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Industrial QUALITY CONTROL

Vol. XIV, No. 12
June, 19

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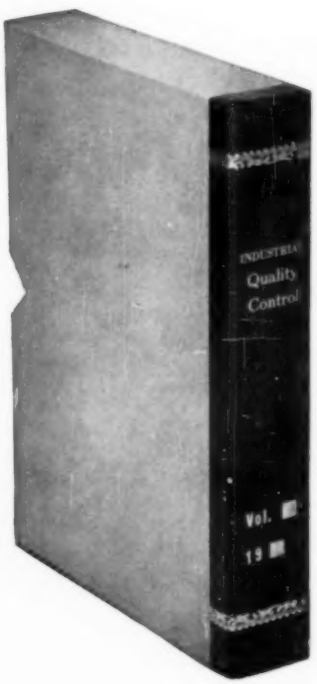

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Quality Control

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From the President's Desk

Our Professional Development—A Status Report

The February issue of *Industrial Quality Control* contained an article on the current program of the Society's Committee on Professional Development. The program is designed to promote professional stature and advancement of the Society and of its individual members, and the project envisages a broad-gauged approach to the problem, as evidenced by the nature and scope of its six phases, which are:

1. The development and documentation of the basic elements of the work of the professional quality control engineer.
2. The integration of these professional standards with employers of quality control engineers.
3. The development of educational and self-improvement programs through which local sections may assist members in increasing their membership grade through "moving up the professional chairs."
4. Working with colleges and universities to encourage the introduction of quality control engineering as a particular area of technical education.
5. Working with state and national agencies so as to encourage the recognition of quality control engineering as an area suitable for professional engineering licensing.
6. The outlining of areas of national, state, and local contribution and service by the quality control engineer, in recognition that such public service is an inherent requirement for professionalism.

Progress in the first phase, the Development and Documentation of the Basic Elements of Work of Quality Control Engineering, has been substantial. In the article referred to above, the first efforts in this area were presented with the view to stimulating considered thought and discussion. By this means it is hoped that wide spread acceptance of appropriate Basic Work Elements will result. The comments and suggestions of all members of the Society are earnestly solicited; they should be directed to the Committee on Professional Development, care of our Headquarters' office in Milwaukee. Mr. Robert Schin, a member of the committee, has been assigned the responsibility for integrating these comments and suggestions and reporting on them. Arrangements have been made for a limited number of reprints of the material referred to above and they are available to sections and to individuals for consideration and study.

While there is still further development work remaining in this area, an important adjunct is the implementation of what is essentially the third phase of the project—specifically, the Professional Orientation of the Membership. This is truly a tremendous undertaking, and a planned program of this nature is now under way on a trial basis in a few sections in an attempt to test the procedures developed by the Committee. The program involves work by the sections of

a) creating an awareness and clear definition of the problem of professionalism in Quality Control, and
b) carrying on projects designed to meet the challenge and to enhance the professional stature of the member.

Each of the trial sections, through local committees on professional development, will take the recommended actions, along with others consistent with the over-all objectives, in an effort to achieve significant results in professional advancement. It is hoped that these trial activities will point the way to well-developed, widely-adaptable programs for all sections of the Society.

During the coming year you will be hearing more of this program from fellow members of your section. Here again, as the project progresses the suggestions of all members for improvements of the program will be most welcome.

The second phase of the Professionalism Project, the Integration of the Professional Standards of Quality Control Engineering with Employers of Quality Control Engineers, is now under active development. This program calls for the recognition and use of effective "tools" for the integration processes. Further efforts are now being devoted to working out the details of this project. It is expected that this will necessitate effective steps at all levels of Society activity, i.e., at national, regional, and local levels, with special emphasis on the work of individual members. All will be kept informed of the progress of this phase of the Professionalism program.

Thus far, only preliminary consideration has been given to the other three phases of the project, but we look forward to substantial progress in these areas in the coming months. The Committee on Professional Development would welcome suggestions on all phases of the program, and the Officers of the Society encourage individual participation in these activities by every member of the Society. In this way we can be reasonably sure that the results of the efforts represent the thinking of a large segment of the membership.

Sincerely,

Leon Bass

Psychological Bias in Attribute Sampling

JULIAN H. TOULOUSE

Owens-Illinois Glass Co., Toledo, Ohio

Introduction

EVERY quality control program based on attribute sampling must deal with possible variations in opinions and mental attitudes of the rank and file of the organization charged with conducting it. The vulnerability to error ranges from low, with mechanically or electronically automatic methods, through various degrees of instrumentation including go-no-go methods of measurements, to high vulnerability where methods of opinion and decision must be based on some visual memory, as of size, color, degree, or the like. A preliminary paper* on this subject created enough interest that the subject has been explored further.

This series of studies deals primarily with the problem of "flinching," or hesitation at the decision point, a matter not easy to check or verify. Methods of comparison, such as the analysis of variance and the chi-square test, are generally found useful.

We will consider the following topics in a study of the psychology of inspector bias:

Part I

Several kinds of bias which may be present

How to discover if a bias is present

Part II

A theoretical approach toward the problem

Part III

Two Monte-Carlo simulations of an inspection procedure

Summary

Effect of calling conditions borderline

Possible Kinds of Bias in Attribute Inspection

The time honored descriptions of inspector bias are two in number—that the inspector is reluctant to reject, or over-zealous to reject. To this we add two other types—that of not counting borderline defectives unless there are more than one, more than two, and so on, or of counting borderline effectives as defectives, if there are more than one, more than two, more than three, or the like. In other words, this is the influence of numbers on the inspector. Apparently this procedure has more effect than realized. We think this is the most serious deviation. Let us detail the several kinds of bias or deviation we will consider.

Reluctance to reject:

1. The inspector counts both definite defectives and borderline defectives so long as it doesn't reject the lot; thereafter he counts only the definite defectives. The varying opinions are therefore affected by the proportion of the defectives he considers borderline. If none are borderline, he finds correctly; if all are borderline, he never rejects a lot. He maximizes the accept number and minimizes the reject number. It may seem surprising, but on average good quality, and low proportion of borderlines, he does little damage.

2. The inspector is influenced by the *number* of borderline defectives. When he sees the first one in a sample he temporizes—"this one isn't too bad, but if I see any more like it, I'll count (all of) them." As a result he maximizes his counts of "zero defectives," and minimizes his counts of "one defective." What he is doing is superimposing his personal sampling plan on the regular plan. In this case the proportion of what is called borderline is of great importance, and he can do much damage.

3. The inspector proceeds in the same way, but counts borderline defectives only if there are more than *two* of them, or even only if more than three. He turns in process averages that are extremely low, and for certain proportions of "borderline defectives" rejects few lots, but in the examples used in this discussion, where rejection is made when three defectives are counted, when all defects are considered borderline, he rejects as many lots as if all were considered definite defectives. His reporting of low process average, but high numbers of lots rejected seems incompatible.

Over-zealous to reject:

4. The inspector is not influenced by borderline defectives, but by borderline effectives. The finding of defectives establishes a doubt as to the quality, and when the next defective found will reject the lot, he tightens up to the extent of counting, as defectives, thereafter, any borderline effectives. Again, if the proportion of borderline is low and the general quality is good, he does little damage.

5. The inspector is influenced by the number of borderline effectives, and counts them as defective if there are *more than one* present. In a sense he is the opposite of the inspector who is influenced by the number of borderline defectives. He shows an excess of 3's and 4's in his sampling when 2 is the accept number and 3 the reject number. He minimizes the count of 2.

6. The inspector is similar to the one above, except that he counts the borderline effectives as defectives only if there are more than two of them.

This study does not go into the matter of the latter three types since their handling is obvious from the general treatment used.

Discovery and Analysis Methods

In dealing with practical operation, the true quality is not known *a priori*. One must deal with patterns and comparisons.

*J. H. Toulouse, "Psychological Bias in Inspection," Administrative Applications Conference, Chicago, February 8-9, 1957.

TABLE I

Inspector	Reported Process Average	Reported % Rejected Lots
A	0.55	9.4
B	0.63	13.1
C	0.60	7.5
D	0.83	8.7
Ave.	0.65	9.7

In a situation where there is more than one inspector, each inspecting a portion, or a period, of production, something can be done by way of a start through simple comparisons of process average and percent rejections. In an actual case, to be developed more completely in the course of the article, the following preliminary information from a known occurrence (see Table I) should tell us that the situation was worth going into further.

Examination of the reported process averages brings up the question: Is "D" different from the others? In the percent reject column, is "B" too high, or "C" too low? This simple summary, while stating that the inspectors are not alike, either in reported process average or percent rejects, nor that good correlation exists, does not state that the differences are, or are not, significant; but since they raise a doubt, proper tests can give an answer. Practically speaking, we need to learn how to recognize both the presence and type of bias if we are going to make corrections.

We are aware of the fact that this ignores the question of change in actual quality. We feel that over a long period the variations in quality probably occurred about as frequently and to the same random extent for one inspector as for another. Also, if it were only a matter of quality change, the percent rejected lots should have been in line.

The data just summarized came from an extended study. Operations proceeded "around-the-clock" in three shifts without stoppage during shift change or lunch hour. There were four inspectors, three of whom worked each day. After an inspector had worked five days, his place was taken by another inspector, and after two days he came back to work on another shift. Thus, over a period of time he worked all shifts. Since inspection time was recorded by the hour of the day performed, further comparisons could be made for that variable.

One circumstance made the experimental design non-orthogonal—the number of inspections per hour per shift varied. Because of this, even though it reduced the sensitivity of the significance tests, we resorted to using, for the several inspections summed each hour, the percent defective found.

In explanation of Table II, the figure 0.62 percent for the first hour of the first shift was made up from 13 inspections made during the times "A" actually reported inspections made during the first hour of the first shift. He found "zero" eight times, "one" four times and "four" once, which for a sample of 100 gave 0.62 percent as the process average. Similarly he made 10 checks, each, during the times he worked the 2nd and 3rd hours of the first shift, 8 checks during the 4th hours and so on.

This array means little until we begin to total it for an analysis of variance as in Table III. We do see marked, and in most cases, consistently different totals for the inspectors by shifts, as shown by the line totals, and perhaps between inspectors, and for certain hours.

Now we begin to have a measure of differences. The total for Inspector "D" was 19.91, for "A" 16.89, for "C" 16.50, and "B" 8.59. There was nearly a two-fold difference between "B" and either "A" or "C", and nearly a 2.5:1 ratio between "B" and "D".

Also, by hours, there was considerable variation—over a two-fold difference between the 6th and 8th hours, and nearly as much between the 8th compared with the 1st, 2nd and 3rd hours. The 4th hour total was nearly as small as that for the 8th hour.

Now in Table IV let us sum by shifts instead of inspectors. The shift totals show some similarity, particularly for the first and second shifts.

Even without resorting to an analysis of variance, one could surmise that while the inspectors were excessively variable, the shifts were not. An analysis of variance was made, however, with the results shown in Table V.

It appears that the weak spots are the inspectors (they are significantly different), the hour of the shift (the 8th and 4th hours are really different in results) and the shift-hour interaction. (Finding: the lunch periods differed, and the consequent "hurry-up" came at different times for different shifts). There was no significant difference between shifts, nor did the inspectors change their attitude on different shifts.

TABLE II—Basic Inspection Data, Reported Percent Defective

Insp.	Shift	Hour of Shift 1	2	3	4	5	6	7	8	Totals
A	1	0.62	1.05	1.06	0.43	1.23	1.00	0.40	0.50	6.29
	2	0.67	1.06	1.09	0.00	1.00	1.33	0.81	0.29	6.25
	3	0.63	0.17	0.69	0.70	0.56	0.71	0.75	0.14	4.35
B	1	0.30	0.08	0.30	0.86	0.18	0.93	0.17	0.28	3.10
	2	0.69	0.21	0.20	0.80	0.11	0.11	0.38	0.17	2.67
	3	0.47	0.11	0.46	0.50	0.17	0.50	0.33	0.28	2.82
C	1	1.40	0.63	1.00	0.00	0.33	1.10	0.00	1.00	5.46
	2	0.75	0.50	1.30	0.67	0.64	0.83	0.50	0.50	5.69
	3	1.00	0.88	0.50	0.40	0.38	1.29	0.80	0.10	5.35
D	1	0.90	1.00	0.82	0.82	0.40	1.09	1.08	0.86	6.97
	2	0.67	0.93	1.05	0.55	1.00	0.59	1.41	0.50	6.70
	3	0.54	1.22	0.47	0.00	1.52	1.43	1.06	0.00	6.24

TABLE III—Sums by Inspectors from Table II

Insp.	Hours of Shift 1	2	3	4	5	6	7	8	Total
A	1.92	2.28	2.84	1.13	2.79	3.04	1.96	0.93	16.89
B	1.46	0.40	0.96	2.16	0.46	1.54	0.88	0.73	8.59
C	3.15	2.01	2.80	1.07	1.35	3.22	1.30	1.60	16.50
D	2.11	3.15	2.34	1.37	2.92	3.11	3.55	1.36	19.91
Total	8.64	7.84	8.94	5.73	7.52	10.91	7.69	4.62	61.89

TABLE IV—Sum by Shifts from Table II

Shift	Hours of Shift 1	2	3	4	5	6	7	8	Total
1	3.22	2.76	3.18	2.11	2.14	4.12	1.65	2.64	21.82
2	2.78	2.70	3.64	2.02	2.75	2.86	3.10	1.46	21.31
3	2.64	2.38	2.12	1.60	2.63	3.93	2.94	0.52	18.76
Total	8.64	7.84	8.94	5.73	7.52	10.91	7.69	4.62	61.89

TABLE V—Analysis of Variance

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	F Ratio	$F_{0.05}$	$F_{0.01}$
Inspectors	2.92189	3	0.97396	10.05*	2.83	4.29
Shift	0.16798	2	0.08349	0.86	3.22	5.15
Hour	2.17785	7	0.31112	3.21*	2.24	3.10
Insp.-Shift	0.19280	6	0.05213	0.64	2.32	3.26
Insp.-Hour	1.40268	21	0.06679	0.69	1.82	2.35
Shift-Hour	3.49885	14	0.24992	2.58*	1.94	2.54
Residual	4.06934	42	0.09688			
Total	14.43139	95				

*Greater than either $F_{0.05}$ or $F_{0.01}$

TABLE VI—Actual Findings Reported by Inspectors

No. of Defectives	Inspector A	B	C	D	Total
0	137	174	124	119	554
1	80	54	58	84	276
2	3	15	2	17	37
3	7	11	4	9	31
4	4	6	10	7	27
5	1	3		3	7
6		2	1	2	5
Total Lots Insp.	232	265	199	241	937
Defects	128	168	120	200	616
% Defects	0.5517	0.6340	0.6030	0.8299	0.6574
Lots Rejected	12	22	15	21	70
% Rejected	5.172	8.302	7.538	8.714	7.471

TABLE VII—Chi-Square Test of Data in Table VI

Number of Defectives	Inspectors A	B	C	D	Total
	Theoretical Binomial Distribution of Lots				
0	134	140	109	104	484
1	74	90	66	88	321
2	20	28	20	36	105
3 or more	4	7	4	13	27
	Chi-Square Test				
0	0.07	8.26	2.06	2.16	10.12
1	0.49	14.40	0.97	0.18	6.31
2	14.45	6.04	16.20	10.03	44.04
3 or more	16.00	32.14	30.25	4.92	68.48
Total	31.01	60.84	49.48	17.29	128.95
	"Sign" (+ When Actual Exceeds Theory)				
0	+	+	+	+	+
1	+	−	−	−	−
2	−	−	−	−	−
3 or more	+	+	+	+	+

TABLE VIII—Inspectors Who Loosen up on Borderline Defects

Order of finding defectives reading left to right in "Comb." column
Definite Rejects (R) = 0.9%, Borderline Defectives "B" = 0.1%, N = 100

c	Binomial	Comb.	Prob. of Comb.	Binom.-Comb.	Defects Counted Per Inspector A	B	C	D
0	0.3660323	0	1	0.3660323	0	0	0	0
1	0.3697297	R	0.9	0.3327571	1	1	1	1
		B	0.1	0.0369730	1	1	0	0
			1.0					
2	0.1848648	RR	0.81	0.1497407	2	2	2	2
		RB	0.09	0.0166379	2	2	1	1
		BR	0.09	0.0166379	2	2	1	1
		BB	0.01	0.0018486	2	2	2	0
			1.00					
3	0.0609992	RRR	0.729	0.0444684	3	3	3	3
		RRB	0.081	0.0049409	3	2	2	2
		RBR	0.081	0.0049409	3	3	2	2
		RBB	0.009	0.0005490	3	2	3	1
		BRR	0.081	0.0049409	3	3	2	2
		BRB	0.009	0.0005490	3	2	3	1
		BBR	0.009	0.0005490	3	3	3	1
etc. through c = 6		BBB	0.001	0.0000610	3	2	3	3
			1.000					

TABLE IX—Summary of Series: R = 0.9, B = 0.1

No. of Defectives	Fraction Found Per Inspector A	B	C	D
0	0.366032	0.366032	0.403006	0.404854
1	0.369730	0.369730	0.366033	0.367680
2	0.184865	0.191117	0.166412	0.165289
3	0.060999	0.057668	0.050534	0.049098
4	0.014942	0.012833	0.011535	0.010862
5	0.002898	0.002269	0.002136	0.001925
6 or more	0.000533	0.000350	0.000344	0.000292
	Based on 1,000,000 Samples:			
Defectives	999913	989745	909343	900377
% Defective	0.999913	0.989745	0.909343	0.900377
Lots Rejected	79372	73120	64549	62177
% Lots Rejected	7.9372	7.3120	6.4549	6.2177

Now we have a little more to go on. We can discount any difference due to the environment so far as shift differences go. We know there is a real difference between inspectors, and we know they "let down" at the lunch hour and at the close of day. The latter is probably a matter of discipline and the allowance of more time (or reducing the coverage) during the lunch hour and at the last hour when the paper work is filled out for the shift.

Further analysis of variance, omitting inspector B, showed that there was no significant difference between the remaining inspectors, and omitting the 4th and 8th hours found the remaining hours not significantly different, thus fixing upon Inspector B and the 4th and 8th hours as the weak spots.

Still another test can be made; this is the chi-square test of the distributions of the numbers of defectives per sample.

Table VI gives the distributions by inspectors and total. Table VII completes the chi-square test. Note that the binomial distribution was used to calculate the expected frequencies using the fraction defective reported by the inspector in each case.

The array of the actual data would indicate without further study that the findings are an abnormal distribution. In two cases the curve turns upward (more 3's and 4's than 2's). The other two cases show a plateau.

The chi-square test shows extreme significance in all cases. The totals are all greatly in excess of the 9.21 value associated with 2 degrees of freedom and a significant level of 0.01. In each case, taking the percent of defectives to be that found by the inspectors, the number of lots reported as having 0, 1, 2 or 3 defectives were very significantly different from the numbers to be expected. Thus, there are definite indications that none of these inspectors are accurately reporting the actual numbers of defectives present in lots.

A new factor has been added, that of "Sign". By this we mean that the actual finding for each value of the distribution is greater than theory (+), or less than theory (−). There seems to be a pattern whose recognition will aid in recognizing the kind of bias. It is explored later on in the text referring to Table X. The "signs" here indicate that the inspectors were influenced by the number of defectives *during* the inspection, if we tentatively accept the conclusions of Table X.

On the other hand it will be shown that when the bias is that of reluctance to reject by counting only the definitely defective when the next one counted will reject the lot, the pattern for the distribution of 0, 1, 2, 3, 4, 5, etc. seems to be: − + + − − − −.

This seems to be the case in the theoretical study shown in Table X in the section which follows. When the pattern is one of not counting borderline defectives unless more than one (or two or more) are present, the pattern is + − − + + + + etc., except that when almost all defectives are borderline to the inspector the pattern becomes + + − + + +. Therefore, almost all defectives are borderline to Inspector A, and a large proportion to Inspectors B, C, and D, while all four refuse to count borderline defectives unless there are more than one of them. Thus, the direction of the training needed has become apparent.

TABLE X—Chi-Square Tests for Inspectors B, C, and D

R = 0.9 B = 0.1

No. of Defectives	Inspectors B	Inspectors C	Inspectors D
Binomial Distribution Based on % Defective, Table IX			
0	0.369845	0.401115	0.404766
1	0.369712	0.368098	0.367753
2	0.182941	0.167211	0.165392
3	0.059739	0.050126	0.049087
4	0.014481	0.011115	0.010815
5	0.002780	0.001966	0.001887
6 or more	0.000502	0.000329	0.000300
Chi-Square Test			
0	39.29	8.91	0.0191
1	0.00	11.58	0.0144
2	365.40	3.82	0.0642
3	71.66	3.32	0.0624
4	187.55	15.87	0.2042
5	93.93	14.70	0.7652
6 or more	46.02	0.68	0.2133
Total	803.85	58.88	1.28828
	$\chi^2_{(0.01)}$ for 4 degrees of freedom = 13.277		
	$\chi^2_{(0.10)}$ for 4 degrees of freedom = 7.779		
"Sign" + When Actual Exceeds Theory			
0	−	+	+
1	+	−	−
2	+	−	−
3	−	+	+
4	−	+	+
5	−	+	+
6 or more	−	+	−

Part II

Theoretical Effect of Bias

The conclusions reached in the problem previously discussed referred to a theoretical approach. We are now ready to make such an approach to give the basis for the conclusions made as to the type of bias.

First, it must be recognized that the *order* of finding defectives in the sample affects the decision, particularly if they are divided into defective and borderline defective. This is because in some cases it depends on a borderline defective being seen before or after a definite defective. Adopting the symbol R for definite defectives and B for borderline defectives, the inspector who will not count borderline defectives if they cause rejection, will decide differently if the order of finding is RRB, (calling it 2 defectives) than when RBR or BRR (when the reject number reported is 3).

To study this, a number of tables were made up of the probabilities concerned for different mixes of R and B totaling one percent. These tables had columns as follows:

"c", for the number of defectives in a sample of 100.

"Binomial", probability of a given number of defectives.

"Combination", or all combinations of R and B in a given number of defectives.

"Prob. of Comb.", or the probability of the different combinations of R's and B's for the given values of c. This is calculated using powers and products when two or more defectives were present.

TABLE XI—Chi-square Tests Totals, Total Defective = 1.0%

Borderline % Defects	Inspectors		
	B	C	D
0	0.01	0.01	0.01
0.1	803	58	1.29
0.2	3596	1024	46.13
0.3	7683	5779	686
0.4	13210	17998	5471
0.5	23505	45267	24058
0.6	34928	92352	105527
0.7	50381	163168	314302
0.8	69613	266760	872517
0.9	94293	406621	2066025
1.0	125396	601581	1140575

TABLE XII—Percent Defective Reported, According to Ratio of Definitely Defective (R) and Borderline Defective (B)

Total Defective = 1.0%
N = 100 Rejection No. = 3

% Borderline Defective	% Defective Per Inspector			
	A	B	C	D
0.0	1.000	1.000	1.000	1.000
0.1	1.000	0.990	0.909	0.900
0.2	1.000	0.975	0.836	0.803
0.3	1.000	0.969	0.777	0.711
0.4	1.000	0.959	0.731	0.624
0.5	1.000	0.949	0.696	0.544
0.6	1.000	0.939	0.669	0.418
0.7	1.000	0.929	0.651	0.407
0.8	1.000	0.919	0.639	0.350
0.9	1.000	0.908	0.622	0.302
1.0	1.000	0.898	0.639	0.260

TABLE XIII—Percent of Lots Rejected, According to Ratio of Definite Defective (R) and Borderline Defective (B)

Total Defective = 1.0%
N = 100 Rejection No. = 3

% Borderline Defective	% Lots Rejected Per Inspector			
	A	B	C	D
0.0	7.94	7.94	7.94	7.94
0.1	7.94	7.31	6.45	6.21
0.2	7.94	6.50	5.59	4.78
0.3	7.94	5.96	5.25	3.70
0.4	7.94	5.24	5.30	3.03
0.5	7.94	4.48	5.65	2.82
0.6	7.94	3.67	6.18	3.03
0.7	7.94	2.82	6.78	3.70
0.8	7.94	1.93	7.35	4.78
0.9	7.94	0.91	7.77	6.22
1.0	7.94	0.00	7.94	7.94

TABLE XIV—Distributions and Chi-Square Based on 400 Samples.

n = 100 Reject No. = 3

Proportion % Borderline	Inspectors			
	A	B	C	D
	% Process Average			
0.0	0.992	0.992	0.992	0.992
0.1	0.992	0.985	0.912	0.900
0.2	0.992	0.975	0.833	0.827
0.3	0.992	0.970	0.778	0.715
0.4	0.992	0.955	0.728	0.622
0.5	0.992	0.945	0.695	0.540
0.6	0.992	0.932	0.665	0.468
0.7	0.992	0.925	0.650	0.408
0.8	0.992	0.912	0.635	0.348
0.9	0.992	0.905	0.628	0.302
1.0	0.992	0.895	0.622	0.252
	Number of Lots Rejected			
0.0	31	31	31	31
0.1	31	29	26	25
0.2	31	26	22	19
0.3	31	25	21	15
0.4	31	21	21	12
0.5	31	18	23	11
0.6	31	14	24	12
0.7	31	11	27	15
0.8	31	7	29	19
0.9	31	4	31	25
1.0	31	0	31	31
	Chi-Square Total			
0.0	0	0	0	0
0.1	0	0.31	0.17	0.00
0.2	0	1.06	0.38	0.00
0.3	0	2.05	2.74	0.53
0.4	0	4.84	5.91	0.76
0.5	0	8.75*	16.00†	3.35
0.6	0	14.75	30.11	30.00†
0.7	0	20.51	38.29	58.04
0.8	0	22.77	95.41	18.18§
0.9	0	36.28	151.58	53.16
1.0	0	49.44	228.24	165.01

*Significant for df = 3, $\chi^2_{(0.10)} = 6.251$

†Significant for df = 2, $\chi^2_{(0.10)} = 4.605$

§Significant for df = 1, $\chi^2_{(0.10)} = 2.706$, because frequencies of c = 4 were less than 5

TABLE XV—Distribution of n = 100, p = 0.01

c	Probability	Random Numbers	f for 400 Samplings	
			Sampling	(Theory)
0	0.366032	00001 — 36603	146	(147)
1	0.369730	36604 — 73576	150	(148)
2	0.184865	73577 — 92062	73	(74)
3	0.060999	92063 — 98162	24	(24)
4	0.014942	98163 — 99656	6	(6)
5	0.002898	99657 — 99946	1	(1)
6	0.000463	99947 — 99992	0	—
7	0.000071	99993 — 00000	0	—

TABLE XVI—Random Sampling of the System: R = 0.9%, B = 0.1%, n = 100

c	n	Comb.	Ratio	Random No's.	n'	Defects Counted Per Inspector A	B	C	D
						R+B	B<2	>B	>BB
0	146	0	1	All	146	0	0	0	0
1	150	R	0.9	001 — 900	136	1	1	1	1
		B	0.1	901 — 000	14	1	1	0	0
2	73	RR	0.81	001 — 810	59	2	2	2	2
		RB	0.09	811 — 900	6	2	2	1	1
		BR	0.09	901 — 990	7	2	2	1	1
		BB	0.01	991 — 000	1	2	2	2	0
3	24	RRR	0.729	001 — 729	17	3	3	3	3
		RRB	0.081	730 — 810	3	3	2	2	2
		RBR	0.081	811 — 891	2	3	3	2	2
		RBB	0.009	892 — 900					
		BRR	0.081	901 — 981	1	3	3	2	2
		BRB	0.009	982 — 990	1	3	2	3	1
		BBR	0.009	991 — 999					
		BBB	0.001	000					
4	6	RRRR	0.6561	000 — 656	5	4	4	4	4
		RBRR	0.0729	810 — 882	1	4	4	3	3
5	1	RBRRB	0.0073	8756 — 8829	1	5	4	5	3

"Binomial-Ratio", the product of the previous columns two and four.

"A", "B", "C", "D", the decisions made by four theoretical inspectors:

"A", correct

"B", counted "B's" only if they did not reject the lot

"C", counts "B's" if more than one in the sample

"D", counts "B's' if more than two in the sample.

A sample array, extended only in part, is shown as Table VIII.

The summary of Table VIII resulted in Table IX.

Each of the values for percent defective was used to calculate the expected binomial distributions for inspectors B, C, and D in Table X. Inspector A's data is not needed because *a priori*, he calls all defectives perfectly.

We are limited in any practical application because the true defectiveness is unknown. Otherwise comparisons could be made between Inspectors B, C, and D with Inspector A, with a considerable increase in sensitivity. This explains why Inspector D was not shown to be significantly in error (Table XI) until the proportion of borderline defectives exceeded B = 0.2.

Note the regularity of the "signs" for B, C, and D. This pattern seems to be associated with the kind of bias and could help decisions as to the discipline or training to be given. *Use care however, unless the chi-square test shows high significance.*

The chi-square totals for the eleven combinations of R and B resulted in Table XI.

This table immediately shows the rapid growth of the chi-square totals, significant for Inspectors B and C, at any level of borderline decision, and at the B = 0.2 percent level for Inspector D.

It is interesting also to observe what happened to the percent defective, and to the lots rejected by these inspectors for the differing combinations of "R" and "B". These are shown in Tables XII and XIII, respectively.

Note that for Inspector B, who refuses to count any borderline defective if it will reject the lot, there is not much reduction in the process average (Table XII) but there is a steady decrease in lots rejected, down to the point where he rejects none. Inspector C who counts borderline defectives only if there are more than one in the sample, reports an ever-decreasing process average, until it drops to two-thirds the true value. He rejects fewer and fewer lots, to a minimum at B = 0.3 percent, then increases until he holds as many at B = 1.0 percent as he did when B = 0.0 percent. Inspector D reports process averages decreasing steadily to one-fourth the true value, but like Inspector C, rejects fewer and fewer, until he reaches a low at B = 0.5 percent, then climbs back to the initial value. With Inspectors C and D we have the phenomenon of decreasing process average, but increasing rejection, when the proportion of borderline defectives increases beyond half the defectives present.

Because operating conditions would be concerned with far fewer than 1,000,000 samplings, we also converted to the proportionate numbers with 400 samples, with only slightly different results. In this, of course, we used only whole numbers with the combined frequencies totaling 400.

In Table XIV, particularly, note the loss of sensitivity of the chi-square test, even by going to the 0.10 probability, when the number of observations decreased.

PART III

Monte Carlo Simulations of an Inspection Procedure

Two approaches to the determination of an inspector bias were made using Monte Carlo methods—by a bead box, and by random numbers. They further demonstrate the effect of bias, but also show the need for good data and ample sampling.

TABLE XVII—Results of Sampling the System: R = 0.9%, B = 0.1%, n = 100

c	Inspectors A	B	C	D
	Number of lots in 400			
0	146	146	160	161
1	150	150	149	150
2	73	77	66	65
3	24	20	19	19
4	6	7	5	5
5	1		1	
n	400	400	400	400
Total Defective	397	392	363	357
% Defective	0.99	0.98	0.91	0.89
Lots Rejected	31	27	25	24
% Lots Rejected	7.75	6.75	6.25	6.00
	Binomial distribution according to % defective			
0	148	150	161	163
1	147	148	147	147
2	73	72	67	66
3	24	23	20	19
4+	8	7	5	5
Chi-square totals (none significant)	0.21	0.88	0.30	0.10

TABLE XVIII—Monte Carlo (Random Number) Analysis of Systems, R + B = 1.0%, a = 100

%B	Inspectors A	B	C	D
	% Defective			
0.0	0.99	0.99	0.99	0.99
0.1	0.99	0.98	0.91	0.89
0.2	0.99	0.97	0.82	0.77
0.3	0.99	0.96	0.79	0.74
0.4	0.99	0.95	0.74	0.63
0.5	0.99	0.94	0.68	0.55
0.6	0.99	0.93	0.68	0.48
0.7	0.99	0.92	0.63	0.42
0.8	0.99	0.91	0.64	0.35
0.9	0.99	0.90	0.60	0.32
1.0	0.99	0.90	0.62	0.25
	Lots Rejected in 400			
0.0	31	31	31	31
0.1	31	27	25	24
0.2	31	25	20	16
0.3	31	20	18*	13
0.4	31	19	19	12
0.5	31	15	22	12
0.6	31	14	26	10*
0.7	31	9	26	17
0.8	31	5	31	20
0.9	31	4	30	25
1.0	31	0	31	31
	Chi-square Test			
0.0	0.21	0.21	0.21	0.21
0.1	0.21	0.88	0.30	0.10
0.2	0.21	5.73	0.38	0.10
0.3	0.21	5.16	0.41	0.23
0.4	0.21	6.80†	3.51	0.68
0.5	0.21	12.40	13.90§	5.15§
0.6	0.21	16.99	36.06	7.06
0.7	0.21	32.87	62.76	10.56
0.8	0.21	90.64	105.60	14.82
0.9	0.21	37.78	132.13	42.04
1.0	0.21	47.71	228.11	126.59

*Indicates minimum value.
†Significant to 0.10 level, 3 degrees of freedom
§Significant to 0.10 level, 2 degrees of freedom, since frequency of C = 5, dropped to less than 5.

In the random number approach the procedure was as follows:

> Sampling was first made according to the probability of finding 0, 1, 2, 3, etc. defectives in a sample of 100, as shown in Table XV. Then, by 400 samplings from a table of random numbers, the frequency of 0, 1, 2, 3, etc. defectives in a sample of 100 was chosen. The result was quite close to theoretical.

This was taken as the master distribution for all studies of a series of systems where R + B = 1.0 percent. The theoretical values, from the binomial distribution, are shown in parentheses.

Next, a series of random number intervals was set up for each value of "c", divided in proportion to the "R" and "B" values in their various combinations. This is shown, (for R = 0.9 percent, B = 0.1 percent) in Table XVI. Also, in Table XVI, in the column "n'" is the number of times a random number came up in each interval. The total for n' for any one value of "c" must equal the value of "n" for that value. In other words, each value of "c" was sampled by random numbers as many times as indicated by the value "n".

For values of c = 4 and c = 5, the table omits combinations on the work sheets which did not show up in the drawing of random numbers. In the last four columns appear the count of defectives for four inspectors, depending on their individual bias:

A – counts all R's and B's.

B – (B<2) counts "B" only when the count of defectives is less than 2.

C – (>B) counts B only if there is more than one "B".

D – (>BB) counts B only if there are more than two "B's".

This resulted in the compilation in Table XVII of the comparisons with the theoretical distribution according to the process average calculated for each inspector. The chi-square calculations are shown.

The results of sampling and analysis of all eleven systems, of R + B = 1.0 percent by tenths of a percent from R = 1.0 percent, B = 0.0 percent to R = 0.0 percent, B = 1.0 percent are exhibited in Table XVIII.

Table XVIII would say that it would be difficult to detect bias unless the degree of "borderline-ness" was at least half of the defectiveness, with as few as 400 observations, and

TABLE XIX—Monte Carlo (Bead Box) Analysis of Systems, R + B = 1.0%, n = 100

Comb.	n	Inspectors A	B	C	D
		Defect Finding			
0	69	0	0	0	0
R	38	1	1	1	1
B	36	1	1	0	0
RR	10	2	2	2	2
RB	9	2	2	1	1
BR	12	2	2	1	1
BB	7	2	2	2	0
RRR	2	3	3	3	3
RRB	4	3	2	2	2
RBR	1	3	3	2	2
RBB	1	3	2	3	1
BRR	3	3	3	2	2
BRB	1	3	2	3	1
BBR	2	3	3	3	1
BBB	3	3	2	3	3
BRBB	1	4	2	4	4
BBRR	1	4	4	4	2
c		Number Reported			
0		69	69	105	112
1		74	74	59	63
2		38	48	25	19
3		17	8	9	5
4		2	1	2	1
n		200	200	200	200
Defectives		209	198	144	120
% Defective		1.045	0.990	0.720	0.600
Lots Rejected		19	9	11	6
% Lots Rejected		9.5	4.5	5.5	3.0
c Bin. Dist.		Chi-Square Test			
0		70	74	97	110
1		74	74	70	66
2		39	36	25	24
3 or more		17	16	7	
Chi-square Total		0.275	7.400	4.674	0.213
d-f		2	2	2	1
$\chi^2_{.10}$		4.605	4.605	4.605	2.706
Significant?		no	yes	yes	no

that the use of any fewer observations would increase the difficulty. This observation could be made equally well from Table XIV.

Another method for a Monte Carlo approach is the bead box. We give an example, only. In a population of 1000 beads, 5 each were Red (Rejects) and Blue (Borderline). Two hundred samplings, with replacement, of 100 each (two consecutive samplings of a 50 by 50-place paddle) were made, in which there was an arbitrary numbering of the holes in the paddle, and the order of "finding defectives" was according to the position in the sampling paddle. These results are shown, summarized and tested in Table XIX.

The chi-square test shows significance at the 0.10 level for Inspectors B and C but not for Inspectors A and D. The difficulty lies probably in two factors: the small number of lots and the resulting low degrees of freedom, since in the case of Inspector D it results in combining a figure for $c = 2$ (of negative value as shown earlier) with that for $c = 3$ or more (a positive value), thus cancelling each other in expectancy. A more sensitive test is needed.

The Effect of Calling Conditions Borderline

We can summarize that there are two effects from calling conditions borderline. The first is that a wide zone of indecision makes for significant differences according to the individual inspector bias, and that the primary training must be to reduce the size of this zone. The second is that it results in great difference in the number of lots rejected, up to three-fold or more. Consequently the results of inspection, and the quality passed, vary greatly.

A test of moderate sensitivity can be made which will guide in the necessary training and retraining. Its use together with the recognition of the systematic difference between theory and actual defectives found will aid in the discovery of the kind of bias that is present.

Operating Characteristic Curves

for the lot plot sampling inspection plan when population is normal

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Introduction

The Hamilton Standard Lot Plot Method of Acceptance Sampling by Variables was developed as an improvement over the classical plan of sampling by attributes. It is intended to avoid the weakness of some plans of sampling by variables, namely, the *a priori* assumption of a specific probability distribution for a characteristic which is measured in the sample. The lot plot method is conducted in two phases, the second being dependent on the first: (1) The sample is divided into k subsamples of n each (number of items in original sample = kn) and a histogram for the measured characteristic is obtained from the kn items. The statistics $\bar{X}$ (the sample mean) and $\bar{R}$ (the mean range over the k subsamples) are computed. (2) From the appearance of the histogram, a decision is reached as to the type of population from which the sample came; the original work on this method considered eight types of populations. With the parent population now taken as known (in type only) a method, appropriate to the population, is given for using the statistics previously computed in deciding whether to accept or reject the lot which was sampled. The details of this plan and a discussion of some theoretical aspects of it are found respectively in References (1) and (2).

The original presentation [1] gives very little discussion of the power of the plan, and no discussion of how the power changes as the plan is modified. In this article, some flexibility is introduced to allow a plan to be set up for which the acceptance probability with a certain percentage of defectives is predetermined. This work is limited to the situation where the parent population is normal; the examination and classification of the sample histogram is of no concern here. For a discussion of the effects of an incorrect decision on the population see Ref. (2).

The procedure for calculating an operating characteristic curve for a generalized plan follows. An example has been worked out and follows the procedural outline.

Power of the Generalized Plans

With each item of a lot we associate a measurable continuous characteristic (e.g., length, resistivity, etc.) which is interpreted as a random variable over the lot. The value of this characteristic for the i-th member of a sample from the lot will be denoted by X_i, where this value is assumed to be free of measurement error. This member is an acceptable item if X_i lies in a prespecified interval (L_1, L_2), otherwise not. Since the lot as a whole is to be accepted or rejected, we agree that a certain fraction of non-acceptable items will have to be included unless a perfect 100 percent sampling is used. Denoting by prime the true fraction of non-acceptable items, it is desired to construct a statistic which is conveniently used in an acceptance procedure with the

following property: Given δ and p_0, the lot will be accepted with probability δ if $p' = p_0$. This gives an acceptance probability greater than δ if $p' < p_0$ and less than δ if $p' > p_0$.

We suppose that the characteristic measurement X is normally distributed with mean $\overline{X}'$ and variance σ'^2 Given L_1 and L_2, we define two new parameters l_1 and l_2 by $L_1 = \overline{X}' + l_1\sigma'$, $L_2 = \overline{X}' + l_2\sigma'$. These are related to p' by

$$\Pr\left\{\overline{X}' + l_1\sigma' < X < \overline{X}' + l_2\sigma'\right\} = 1 - p'$$

or

$$\frac{1}{\sqrt{2\pi}}\int_{l_1}^{l_2} e^{-x^2/2}\, dX = 1 - p'.$$

An additional relation between l_1 and l_2 is needed to determine them as a function of p'. In the examples we shall take $l_1 + l_2 = 0$.

From $\overline{X}$ and $\overline{R}$ (already computed) we determine two statistics w_1 and w_2, given by

$$\left.\begin{aligned} w_1 &= \overline{X} + q_1\overline{R} \\ w_2 &= \overline{X} + q_2\overline{R} \end{aligned}\right\} q_2 > q_1$$

where q_1 and q_2 are constants determining the plan;* in most cases, we will have $q_2 > 0 > q_1$, but the analysis given here covers the more general situation of simply $q_2 > q_1$. In this work specific values for q_1 and q_2 will be determined later as functions of p_0 and δ, whereas in Ref. (1) the fixed numbers $q_2 = -q_1 = 1.3$ are used; the choice allowed for q_1 and q_2 is the flexibility referred to earlier. (In the examples discussed here, we will also consider the special case $q_1 + q_2 = 0$.) The acceptance rule to be used reads as follows:

A. Calculate w_1 and w_2.

B. Check the inequalities $L_1 < w_1 < L_2$, $L_1 < w_2 < L_2$.

C. If either inequality is violated, reject the lot, otherwise accept it.

The probability of accepting a lot with a fraction defective p' is then

$$P = \Pr\left\{L_1 < w_1 < w_2 < L_2 \mid p'\right\}.$$

The satisfaction of the defining property of the plan as given above implies

$$\Pr\left\{L_1 < w_1 < w_2 < L_2 \mid p' = p_0\right\} = \delta.$$

We must now get the expression for P into a workable form.

The mean range, $\overline{R}$, for the sample sizes involved here, is approximately normally distributed as (see Ref. 3)

$$\overline{R}\colon\ N\left(a_n\sigma',\ \frac{\beta_n^2\,\sigma'^2}{k}\right)$$

where a_n (which is the same as d_2) and β_n have been tabulated[4]. Hence we have

$$w_1\colon\ N[\overline{X}' + q_1a_n\sigma',\ Q^2(q_1^2)\ \sigma'^2]$$

$$w_2\colon\ N[\overline{X}' + q_2a_n\sigma',\ Q^2(q_2^2)\ \sigma'^2]$$

*There is no relation between q and p of the form $q = 1 - p$ in this article; the q_i and q_2 are simply modifiers of $\overline{R}$.

where

$$Q^2(q_i^2) = \frac{1}{k}\left[\frac{1}{n} + q_i^2\beta_n^2\right]\quad i = 1, 2$$

It is convenient to define two new variates u_1 and u_2 by

$$u_1 = \frac{w_1 - \overline{X}' - q_1a_n\sigma'}{Q(q_1^2)\sigma'}$$

$$u_2 = \frac{w_2 - \overline{X}' - q_2a_n\sigma'}{Q(q_2^2)\sigma'}.$$

It is clear that u_1 and u_2 are both normally distributed with zero mean and unit variance. Since $w_1 = Q(q_1^2)\sigma'u_1 + \overline{X}' + q_1a_n\sigma'$, the inequality

$$L_1 < w_1 < L_2$$

is equivalent to

$$\overline{X}' + l_1\sigma' < Q(q_1^2)\sigma'u_1 + \overline{X}' + q_1a_n\sigma' < \overline{X}' + l_2\sigma'$$

or

$$\frac{l_1 - q_1a_n}{Q(q_1^2)} < u_1 < \frac{l_2 - q_1a_n}{Q(q_1^2)}.$$

For brevity we let

$$\theta_{ij} = \frac{l_j - q_ia_n}{Q(q_i^2)}\quad i, j = 1, 2.$$

The notable feature of the θ_{ij} is that they do not contain explicitly the parameters, $\overline{X}'$ and σ', of the parent population. (Note that the l_j are determined from a standardized normal distribution.) The inequality $L_1 < w_2 < L_2$ may be reduced in a manner similar to that given above, and we then obtain

$$P = \Pr\left\{\theta_{11} < u_1 < \theta_{12};\ \theta_{21} < u_2 < \theta_{22}\right\}$$

This is readily evaluated since the distributions of u_1 and u_2 are known. The problem is completed once the correlation between u_1 and u_2 is computed. We have

$$\rho = E(u_1u_2),$$

since u_1 and u_2 have zero means and unit variances. Substitution in terms of $\overline{X}$ and $\overline{R}$, and using $E(\overline{X} - \overline{X}')^2 = \sigma'^2/nk$ and $E(\overline{R} - a_n\sigma')^2 = \beta_n^2\sigma'^2/k$ gives

$$\rho = \frac{1}{Q(q_1^2)Q(q_2^2)\sigma'^2}\left\{\frac{\sigma'^2}{nk} + q_1q_2\frac{\beta_n^2}{k}\,\sigma'^2 + (q_1 + q_2)E\left[(\overline{X} - \overline{X}')(\overline{R} - a_n\sigma')\right]\right\}.$$

But the mean range is independent of the sample mean for a normally distributed variable,[5] so $E(\overline{X} - \overline{X}')(\overline{R} - a_n\sigma') = 0$. This gives

$$\rho = \frac{Q^2(q_1q_2)}{Q(q_1^2)Q(q_2^2)}$$

where

$$Q^2(q_1q_2) = \frac{1}{k}\left[\frac{1}{n} + q_1q_2\beta_n^2\right];$$

TABLE I

q	ρ
0.423	0.2
0.518	0
0.634	−0.2
0.705	−0.3
0.745	−0.35
0.790	−0.4
0.840	−0.45
0.897	−0.5
0.960	−0.55
1.03	−0.6
1.12	−0.65
1.23	−0.7
1.37	−0.75
1.55	−0.8

note that ρ is also independent of $\bar{X}'$ and σ'. With this value known, P may be expressed as

$$P = \frac{1}{2\pi\sqrt{1-\rho^2}} \int_{\theta_{21}}^{\theta_{22}} \int_{\theta_{11}}^{\theta_{12}} \exp\left[-\frac{u_1^2 - 2\rho u_1 u_2 + u_2^2}{2(1-\rho^2)}\right] du_1 du_2.$$

Tables for the evaluation of this integral have been contructed and should be consulted for numerical work[6, 7].

We now have P as a function of p', q_1, q_2, n, k where n and k are presumed fixed; l_1 and l_2 have been determined by P and some additional relation. The constants q_1 and q_2 are then determined by

$$P(p', q_1, q_2) = \delta \text{ when } p' = p_0.$$

A summary outline of the computations needed to find a plan to meet the criterion just given and then to construct an operating characteristic curve (P vs. p') is given in the following example.

Example

To illustrate the work just presented we consider a special case defined by the following:

$$l_2 = -l_1 = l$$
$$q_2 = -q_1 = q$$
$$n = 5$$
$$k = 10$$

The problem is twofold: (A) to determine a specific plan such that P = 0.9 when $p' = 0.02$, and (B) to generate the OC curve for this plan.

In this work the acceptance probability P is a function of both p' and q. P(q) represents P as a function of q with p' held fixed at some desired specified value, while P(p') represents P as a function of p' with q held fixed.

The calculations proceed according to the outline below. Here part (A) is covered in steps 1 through 4, and part (B) in steps 5 through 7.

1. For a succession of reasonable values of q, tabulate ρ as a function of q. This has been done here in such a way as to facilitate the use of existing tables of the integral of the bivariate normal, that is, by solving the equation for q in terms of ρ and substituting values for ρ. Values of q vs. ρ are shown in Table I and Fig. 1.

2. Compute θ_{11}, θ_{12}, θ_{21}, θ_{22} for a succession of reasonable values of q, using $l = 2.33$ which corresponds to $p' = 0.02$. Note that $\theta_{11} = -\theta_{22}$, $\theta_{12} = -\theta_{21}$; we have let $\psi_1 = \theta_{11}$, $\psi_2 = \theta_{12}$ for brevity.

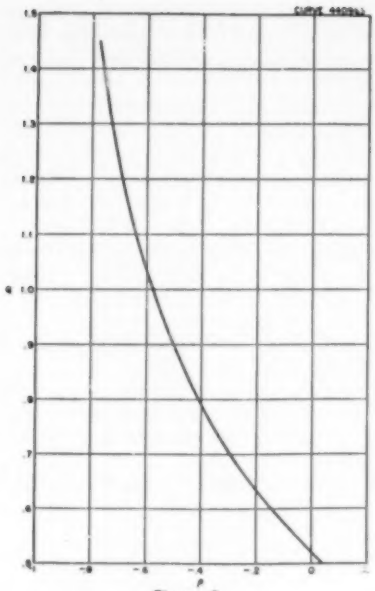

Figure 1

3. Using the values of ψ_1 and ψ_2 just obtained, calculate P(q) for the q values being considered. If

$$B(h, k; \rho) = \frac{1}{2\pi\sqrt{1-\rho^2}} \int_{k}^{\infty} \int_{h}^{\infty} \exp\left[-\frac{X^2 - 2\rho XY + Y^2}{2(1-\rho^2)}\right] dX dY$$

then a convenient approximation to P(q) when $\psi_2 > 5$ is

$$P = B(\psi_1, \psi_1; -\rho) \qquad \text{when } \psi_1 > 0$$

or

$$P = B(-\psi_1, -\psi_1; -\rho) + \frac{2}{\sqrt{2\pi}} \int_{0}^{-\psi_1} e^{-x^2/2}\, dX$$

when $\psi_1 < 0$. The numerical work reported here was carried out with the aid of the tables in Ref. (7).

4. Determine the value of q satisfying P(q) = 0.9. In this example an approximate solution was found to be q = 0.79, which is a value giving a simple value for ρ.

5. Using q = 0.79, compute ψ_1 and ψ_2 for a succession of values of p' over the range of interest (p' determines l_1 and l_2, and these give θ_{ij}'s or ψ_i's.

6. With these values of ψ_1 and ψ_2, calculate P(p') corresponding to the values of p' being considered. Numerical results for this example are shown in Table II. (Also shown in Table II are values of P(p') for two other values of q, namely q = 0.897 and q = 1.23.)

TABLE II

p'	q = 0.790	q = 0.897	q = 1.23
0.005	0.99994	0.989	0.322
0.01	0.996	0.916	0.128
0.02	0.947	0.691	0.032
0.03	0.826	0.451	0.010
0.04	0.665	0.272	0.004
0.05	0.521	0.175	0.002
0.06	0.382	0.103	0.001
0.07	0.270	0.062	0.000
0.08	0.191	0.040	0.000

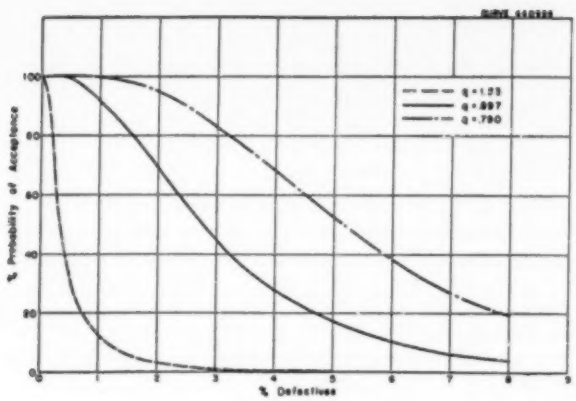

Figure 2

7. The operating characteristic curves may now be plotted directly. Three such curves are shown on Fig. 2.

References

(1) Shainin, Dorian, "The Hamilton Standard Lot Plot Method of Acceptance Sampling by Variables," *Industrial Quality Control*, Vol. VII, No. 1, July 1950, p. 15-34

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(4) Hald, Anders, *Statistical Tables and Formulas*, John Wiley & Sons, Inc., 1952, Table VIII

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A Missiles Seriousness and Complexity

Vendor Rating System*

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Synopsis

This article proposes a vendor rating system, based on varying product complexity and defect seriousness, for the purpose of supplying management with a simple but effective tool for making decisions concerning vendors.

Such a system is highly desirable because (1) it can be used with very small lot sizes, e.g., R & D lot sizes and (2) it compares vendors with vendors and products with products, i.e., an electrical vendor with a mechanical vendor and a bracket with a television receiver.

The initial planning cost is reduced by a "quick and dirty" method of establishing AQLs. The types of defects detected were ranked in order of seriousness and were divided into three weighted classes, critical, major, and minor.

The occurrences of weighted defects follow the Poisson distribution ("c" chart principle), and the monthly Part Ratings are based upon the cumulative Poisson distribution. The Vendor Rating is based upon (1) the results of the Part Ratings, (2) the number of part-number lots, and (3) the cumulative binomial distribution. Then, a generalization is made whereby management has only one over-all rating to consider for the general quality level and trend. A simple example is included to indicate the various steps, principles, and results.

The vendor rating system has been set up for IBM card processing from the receipts of the units at the incoming dock, through inspection and computations, to the final form which is distributed to all involved departments.

*The procedure reported in this article was developed while the author was Mathematician at the Bendix Aviation Corporation, Mishawaka, Indiana.

Assigning AQLs By Complexity of Part or Assembly

The first step taken in establishing the vendor rating system was to review the incoming products (defined as parts, sub-assemblies, and assemblies) for the purpose of determining the defect distributions and the AQLs.

It was found that (a) a statistical measure of defects per unit was the most applicable for rating, (b) the number of defects per unit was a function of the complexity of the product, and (c) a positive relationship exists between the product cost and product complexity. The multimodal distribution of products permitted easy and nearly homogeneous groupings for ranking. With this information, a rank of complexity was

achieved easily. The "quick and dirty" method is to assign the low (loose) AQL for the most complex product with graduated AQLs up to the high (tight) AQL for the simple product.

The Acceptable Quality Level derived from the rank of product complexity will be expressed as

$$AQL = AQL \text{ by product complexity} \quad (1)$$

The AQL is expressed as the average defects in 100 units for all AQLs. Let N equal the quantity of units in the part-number lot under consideration, then N/100 is the proportional part of 100 units, and

$$D = AQL\ (N/100) \quad (2)$$

where D is the expected average number of defects in N units for a specified AQL.

When considering the expression (1), equation (2) can be further expanded as the expected average defects in a part-number lot of N units at the product complexity AQL.

Assigning Weights to Types of Defects

The types of defects were classified daily for cause and seriousness by a group of reliability engineers. A survey was made among the engineers for seriousness rank order of the various types of defects. The rank order was divided into three classes, critical, C, major, M, and minor, m; and the weights, 4, 2, and 1, were assigned respectively. Another way to express the weights and defect seriousness weights is as follows:

$$\begin{aligned} W_C &= 4 \text{ for critical type defects} \\ W_M &= 2 \text{ for major type defects} \\ W_m &= 1 \text{ for minor type defects} \\ W_v &= \text{a general symbol for any of the above three weights.} \end{aligned} \quad (3)$$

Weighted defect types are expressed as

$$\begin{aligned} d_C W_C &= \text{weighted critical defects in terms of minor defects} \\ d_M W_M &= \text{weighted major defects in terms of minor defects} \\ d_m W_m &= \text{weighted minor defects in terms of minor defects} \\ d_v W_v &= \text{the various weighted defects listed above where } v = C, M, m. \end{aligned} \quad (4)$$

The weighted defects, $d_v W_v$, for critical, major, and minor levels of seriousness are assigned to take ratio values.

$$d_C W_C : d_M W_M : d_m W_m = 4:2:1 \quad (5)$$

For instance, consider a part having $x = d_m$ allowable minor defects. The resulting allowable defects will be

$$d_C: d_M: d_m = (x/4) : (x/2) : (x/1) \quad (6)$$

Applying the Poisson Distribution for the Part Rating

The summation of the various weighted defects per part-number lot is expressed as

$$\Sigma d_v W_v = (d_C W_C + d_M W_M + d_m W_m) \quad (7)$$

It is observed from equation (6) that equation (7) can be considered in terms of relative minor defects. Therefore, equation (7) is equivalent to c in equation (13) of Appendix A; i.e.

$$c \equiv \Sigma d_v W_v \text{ in actual relative minor defects.} \quad (8)$$

Multiply equation (2) by W_m to obtain

$$DW_m = \frac{AQL \times N \times W_m}{100} \text{ in expected minor defects.} \quad (9)$$

If we let DW_m be the expected average number of relative minor defects in N units at an AQL, equation (9) is equivalent to "a" in equation (13) of Appendix A; i.e.

$$a \equiv DW_m \text{ in expected relative minor defects.} \quad (10)$$

Substituting equation (8) and (10) in equation (14) of Appendix A, rewriting and describing, equation (11) follows

$$PR_n = \sum_{x\,=\,\Sigma d_v W_v}^{\infty} e^{-(DW_m)} \frac{(DW_m)^x}{x!} \quad (11)$$

where

$\Sigma d_v W_v$ = the actual relative minor defects in a part-number lot.

DW_m = the expected relative minor defects in a part-number lot.

PR_n = Part Number Rating numerical = the cumulative probability of $(\Sigma\, d_v W_v)$ weighted defects or more occurring by chance in a distribution with a mean of (DW_m).

PR_n is assigned an alphabetical letter from Table I and then is designated as PR_a, Part Rating alphabetical.

Applying the Binomial Distribution for the Vendor Rating

Using the individual alphabetical part ratings, PR_a, consider the ratings A, B, C, D, and F to be grouped into two classifications: (1) A, B, C and D ratings as the not-F group with the probability of 0.95 and (2) F ratings as the F group with the probability of 0.05. Thus, in the vendor rating portion of this article, the two classifications (1) F and (2) not-F are merely changing the standard notation, p and q, of the binomial distribution equation in Appendix B to fit previously stated terminology. Now, let the different part-number lots be considered as independent; generally, this condition exists. Whenever two or more particular part-number lots can be proved to be dependent, the particular part-number lots will be grouped. Therefore, throughout this section, independence shall be assumed.

In summarizing, let the variables N, c, p and P (c or more/N) of equation (16) of Appendix B be defined as

N' = total number of independent part-number lots from a vendor inspected during a given interval.

C = the number of part-number lots which were classified as **F**, i.e., $PR_a = F$ in the N' number of part-number lots.

P = the probability of an occurrence of $PR_a = F$, in a single part-number lot, P = 0.05.

VR_n = Vendor Rating numerical = the probability of C events or more occurring in N' independent lots from a vendor.

(EDITORIAL NOTE: This article is continued on page 17 which follows the 8-page "Index to Volume XIV," pages A-1 to A-8.)

EDITORIAL NOTE: This article is continued from page 16, which precedes the 8-page "Index to Volume XIV," pages A-1 to A-8.

Form BPD 027 — **BENDIX PRODUCTS DIVISION** — No.
Receiving Insp. Stores — **RECEIVING REPORT**

DATE	REC'D.	CARRIER NO.	DATE SHPT.	TOTAL CHG.	GROSS WEIGHT	F.O.B.

BOX	CTN.	CRT.	POS.	BAG	TRUCK CO.	CHECKED	ACCOUNT NO.	WHERE DELIVERED

RECEIVED FROM

RECEIVED FROM

ORDERED FROM	OUR COUNT	PART NO.	DESCRIPTION

VENDOR'S PACKING TICKET NO. — RECEIVED BY

PIECES REJECTED	FROM	TO	INSPECTED BY
PIECES O.K.	FROM	TO	RECEIVED BY
STOCK ROOM CHG.	OVER	CONTAINERS	DATE
STOCK COUNT	UNDER		

Figure 1—Receiving Report

Rewrite equation (16) of Appendix B as follows

$$VR_n = \sum_{x=0}^{N'} \frac{N'!}{x!\,(N'-x)!}\, P^x\,(1 - \quad)^{N'-x} \qquad (12)$$

which can be interpreted in Table I to achieve VR_a.

Interpreting the Part and Vendor Ratings

The PR_n or VR_n is assigned an alphabetical letter, PR_a and VR_a, for the various probabilities. The numerical rating will have positive values from extremely small decimals to unity. The various probability levels were used which could be assigned descriptions and the common alphabetic ratings, A, B, C, D, and F. It will be noted in Table I that the probability of an F rating is 5 percent and the probability of Not-F rating is 95 percent.

Also, this system will automatically give a vendor or part rating an F if the previous month's vendor or part rating was D. This follows because the probability of a D is approximately 11 percent, and the probability of two consecutive D's is approximately 1.2 percent which is an F. A more accurate method of assigning the automatic F would be to use the PR_n or VR_n*; however, the former is more lenient with the vendor.

Applying a General Quality Level Rating for Management Decisions

The following application is one of several possible to give a general picture. A General Quality Level rating, GQL, of all vendors can be obtained simply by applying equation (12) with the notation that

N = the total number of part-number lots for all vendors.

C = the total number of part-number lots with an F rating for all vendors.

This information (numerical or alphabetical) when plotted, would furnish management with a valuable tool in analyzing over-all conditions and making management decisions.

*The PR_n and VR_n employ the use of: (1) Molina, E. C., *Poisson's Exponential Binomial Limit*, (Table II) D. Van Nostrand Co., Inc., New York, 1942; (2) *Tables of the Exponential Function C^x*, AMS-14, National Bureau of Standards; (3) Lotkin, M., *Tables of the First 200 Factorials to 20 Places*; and (4) *Tables of the Binomial Probability Distribution*, (Table #2) AMS-5, National Bureau of Standards; where the tables are applicable.

An Example

For any particular month let us follow a simplified example of several vendors and several part-number lots; then, we will combine the lots for computing the GQL.

Input Data:

The two basic forms used are the Receiving Report (RR) (see Figures 1 and 3) and the Talos Discrepancy Report (TDR) (see Figures 2 and 4). The RR provides the vendor, part number, part description, quantity received, RR number, date inspected, the TDR serialized number if one or more defects were found, and additional information not relevant to this article.

The TDR provides the vendor, TDR number, type of discrepancy, quantity of defects, and other information not relevant to this article.

BENDIX PRODUCTS DIVISION – MISSILES — TEST EQUIPMENT

No. 09124 INSPECTION & TEST REPORT TAG

Output trace from discriminator was intermittent.

MATERIAL REVIEW BOARD DISPOSITION ONLY

No. 09124

WHERE DETECTED — HOW DETECTED

Figure 2—TALOS Discrepancy Report

Processing the Data

The RR cards, (see Fig. 3) are sorted by part number within vendor and matched with master AQL cards. After this operation, the cards are put into the computer for determining $DW_m = \frac{AQL \times N \times W_m}{100}$.

	Part No.	AQL	Qty R'c'd	TDR No.	DW_m
Vendor X	1234	10.0	1	76	0.1
	1345	0.40	5	81	0.02
	1456	1.5	1	55	0.015

Vendor Y	1356	1.0	2	83	0.02
	1467	15.0	1		0.15
	1468	0.25	4		0.01
	1502	2.5	10		0.25
Vendor Z	1756	0.065	1		0.00065
	1857	1.5	3		0.045
	1862	40.0	5	60	2.0
	1965	0.65	2		0.0135
	1966	2.5	4		0.10
	1978	10.0	1		0.10

The TDR cards are sorted by type of discrepancy, and the defect seriousness weights are gang punched into the TDR cards. The TDR cards are put in an IBM computer for multiplying the defect seriousness weight by the quantity of defects which gives weighted defects per card. In turn, these cards are summarized on weighted defects by TDR number.

	TDR No.	Type of Discrep.	Qty of Defects	Weight	$\Sigma d_v W_v$
Vendor X	76	27	1	4	4
	81	90	1	1	1
	55	3	2	1	2
Vendor Y	83	63	1	2	2
Vendor Z	60	63	1	2	2

Then, the TDR cards are merged with the RR cards and listed.

	Part No.	AQL	Qty R'c'd	$\Sigma d_v W_v$	DW_m
Vendor X	1234	10.0	1	4	0.1
	1345	0.40	5	1	0.02
	1456	1.5	1	2	0.015
Vendor Y	1356	1.0	2	1	0.02
	1467	15.0	1	0	0.15
	1468	0.25	4	0	0.01
	1502	2.5	10	0	0.25
Vendor Z	1756	0.065	1	0	0.00065
	1857	1.5	3	0	0.045
	1862	40.0	5	2	2.0
	1965	0.65	2	0	0.0135
	1966	2.5	4	0	0.10
	1978	10.0	1	0	0.10

Output Data—VR_a and PR_a

At the present time, the volume of probability computations does not warrant machine computation. Generally, these probabilities are easily obtained from Molina's *Poisson's Exponential Binomial Limit*, Table II, and from *Tables of the Binomial Probability Distribution*, by the Department of Commerce. For the sake of brevity only the vendor, part number, probability, and alphabetical rating are listed below.

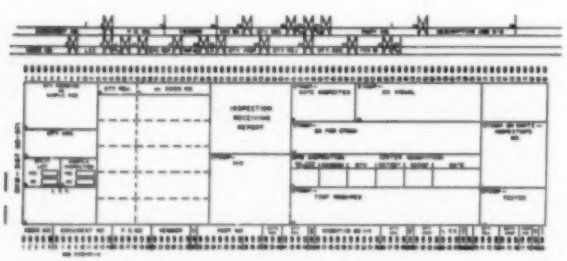

Figure 3—Receiving Report IBM Card

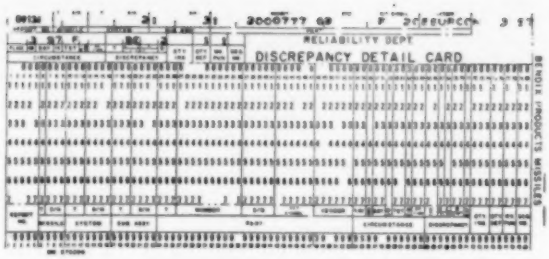

Figure 4—TALOS Discrepancy Report IBM Card

	Part No.	PR_a	PR_a	VR_a	VR_a
Vendor X	1234	0.0000	F	0.0000	F
	1345	0.0198	F		
	1456	0.0001	F		
Vendor Y	1356	0.0002	F	0.1855	C
	1467	1.0000	A		
	1468	1.0000	A		
	1502	1.0000	A		
Vendor Z	1756	1.0000	A	1.0000	A
	1857	1.0000	A		
	1862	0.5940	C		
	1965	1.0000	A		
	1966	1.0000	A		
	1978	1.0000	A		

Those vendors and part numbers with F ratings this month are compared with their previous month's rating; any vendor or part number rating of D or F for two consecutive months is automatically rated "F".

Output Data—GQL:

Now considering the General Quality Level (GQL) for this month, we use only the part ratings for all parts rated. Summarized as follows:

N = 13 part-number lots

C = 4 part-number lots with an F rating.

Turning to N = 13 and C = 4 at P = 0.05 in the Binomial table, it is found that the cumulative probability (GQL_n) equals 0.0031 which corresponds to GQL = F —an inferior general quality level.

TABLE I—Interpretation of PR_a and VR_a

PR_a or VR_a Alpha Code	PR_a or VR_a Probabilities*	Description	Binomial Classifications
A	0.9500 — 1.0000	Superior	Not-F
B	0.8400 — 0.9499	Desirable	Not-F
C	0.1600 — 0.8399	Adequate	Not-F
D	0.0500 — 0.1599	Undesirable	Not-F
F	0.0000 — 0.0499	Inferior	F

*The probabilities refer to the cumulative probability of $\Sigma d_v W_v$ (or C) or more weighted defects (or F classified lots) occurring by chance.

Acknowledgements

The many comments, criticisms and suggestions on this article from the members of the Navy Ordnance Inspection, Reliability, Purchasing and other groups during the initiation, formulation, and presentation were deeply appreciated and welcomed. The writer is especially indebted and thankful to Mr. Robert Young, Technical Writer Supervisor and Mr. Don Rung, Instructor, Notre Dame University for their valuable comments on the presentation and on the mathematics, respectively.

Appendix A—Summary of the Poisson Distribution Characteristics

The Poisson distribution is expressed as

$$P(c) = e^{-a}\frac{a^c}{c!} \qquad (13)$$

where

$e = 2.718^+$

a = expected number of defects in a sample

c = the number of defects occurring in the sample

$P(c)$ = the probability of c events occurring in the sample.

This probability distribution is a discrete function, i.e., the variable c changes in steps—0 defect, 1 defect, 2 defects, etc. In this distribution each unit of a lot must have the same odds of a defect occurring.

The above equation is an individual Poisson term for a specific value of c; and Poisson summation below gives the cumulative probability of c defects or more.

$$P\ (c, a) = \sum_{x=c}^{\infty} e^{-a}\frac{a^x}{x!} \qquad (14)$$

Appendix B—Summary of the Binomial Distribution Characteristics

The binomial distribution is expressed as

$$P(c/N) = \frac{N!}{c!\ (N-c)!}\ p^c\ (1-p)^{N-c} \qquad (15)$$

where

N = the number of independent trials, units, lots, etc.

c = the number of defects or events occurring in N.

p = the probability of a defect or event occurring in any single trial, unit, or lot.

$1-p = q$ = the probability of no defect or event occurring in any single trial, unit, or lot.

$P(c/N)$ = the probability of c event or events occurring in N independent trials.

Also, the cumulative probabilities of c and more events occurring in N trials is expressed as

$$P(c \text{ or more}/N) = \sum_{x=c}^{N}\frac{N!}{x!\ (N-x)!}\ p^x\ (1-p)^{N-x} \qquad (16)$$

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SUPERVISOR'S CIRCLE

PAUL A. ROBERT, *Editor*

Precision Products Co. of Cincinnati, Box 130, Norwood 12, Ohio

Does the Three-Wire System Measure True Pitch Diameter?

STANLEY G. JOHNSON

The Johnson Gage Company, Bloomfield, Conn.

The three-wire system has been, is, and probably will continue to be the accepted method for measuring the pitch diameter of a screw thread. It is simple, direct, and understandable in universal terms. However, the ease of application, the uniformity of measurement over the wires and the wide acceptance without question of the system has frequently resulted in its misapplication. The original intent was and still is theoretically sound, but many have failed to recognize the fact that it is predicated on the assumption that the pitch of the screw thread being measured is perfect.

PITCH—"The distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis." H-28 (1944).

PITCH—"The pitch of a thread is the distance, measured parallel to its axis, between corresponding points on adjacent thread forms in the same axial plane and on the same side of the axis." 1950 Supplement to H-28 (1944).

PITCH DIAMETER—"On a straight screw thread, the diameter of an imaginary cylinder, the surface of which would pass through the threads at such points as to make equal the width of the threads and the width of the spaces cut by the surface of the cylinder." H-28 (1944).

PITCH DIAMETER (SIMPLE EFFECTIVE DIAMETER)—"On a straight thread, the pitch diameter is the diameter of the imaginary co-axial cylinder, the surface of which would pass through the thread pro-

Editor's Comments

Stan Johnson needs no introduction to machine shop men, and he is generally recognized as an expert in the field of thread gaging. He and his brother have written numerous articles on the subject. This is a simple, straightforward presentation of the problems involved in measuring the pitch diameter of threads which should be of interest to all inspection personnel concerned with thread measurement.

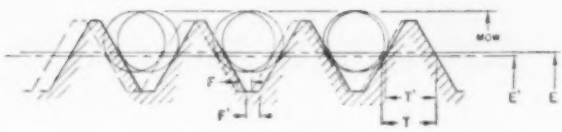

Figure 1—Short Lead

files at such points as to make the width of the groove equal to one-half of the basic pitch. On a perfect thread this occurs at the point where the widths of thread and groove are equal." 1950 Supplement to H-28 (1944).

The latter defines "SIMPLE EFFECTIVE DIAMETER" and should not be confused with the definition of true pitch diameter. Obviously, its application to any thread except one with perfect pitch would result in an "imaginary cylinder" based on "width of space" only which, of course, would be something other than true pitch diameter.

In Figures 1, 2, 3, 4, and 5, the *broken* lines in the thread profile illustrate the correct pitch of the screw thread.

As shown in Fig. 1 illustrating a short lead and Figure 2 illustrating a long lead, conclusive evidence is furnished that the three-wire system fails completely in the measurement of actual pitch diameter. The three-wire system considers the "width of the spaces" only and discounts completely the "width of the threads." In other words, if the definition of pitch diameter is applied, it is obvious that the pitch diameter which is "the diameter of an imaginary cylinder the surface of which would pass through the threads at such points as to make equal the width of the threads and the width of the spaces" is entirely different than indicated by the three-wire measurement.

In Figures 1 and 2 the "width of the spaces" remains constant but the "width of the threads" varies by the amount that the screw thread is long or short in pitch. As illustrated "F" and "F' " remain constant and equal regardless of a longer or shorter pitch or lead. Lengths "F" and "F' " are always equal because they are the function of the "width of the spaces" which, in turn, are the function of the three-wire measurement. The "T' " variations from "T" are equal to the longer or shorter pitch. However, the three-wire measurement remains constant regardless of longer or shorter pitch or lead.

It follows, as shown in Fig. 1 (short lead—a succession of constant short pitches) that the variation in pitch diameter ("E" − "E' ") is proportioned to the variation in the "width of the thread" ("T" − "T' "). In other words, if "T' " is −0.0001 from the correct pitch, "E' " will be 1.732 × 0.0001 or 0.00017 below the pitch diameter as determined by the three-wire measurement.

In Fig. 2 (long lead—a succession of constant long pitches) the converse is true. "T' " which is longer than "T" by the amount of error in pitch is reflected in the pitch diameter "E' " being greater than the pitch diameter "E" (based on perfect pitch) by 1.732 × ("T' " − "T").

This truth can be stated in more simple terms by saying that when the "width of the spaces" only is measured, as is the case when using the three-wire system, a screw with long pitch or lead has a greater cross-section or actual pitch diameter than a screw with short pitch or lead.

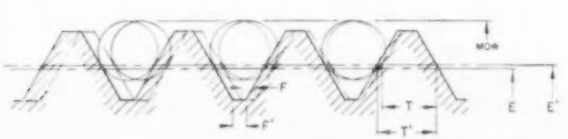

Figure 2—Long Lead

This basic principle is also true in the measurement of a "drunken" thread which may be a screw thread in which the "width of the spaces" is constant while the helix angle is irregular resulting in irregular longer and shorter pitches which result in variations in the "width of the threads" and true pitch diameter at various points. The wire readings would remain constant as the three-wire system measures the "width of spaces" only.

It is agreed that the variations in pitch on thread plug gages and thread plug masters are very slight and perhaps can be discounted to a large degree. However, to be absolutely accurate the pitch of the thread is just as important in net result as the wire size, straightness and roundness, measuring pressure, temperature, etc., when it is borne in mind that 0.0001 in pitch variation results in 0.00017 in pitch diameter variation.

In light of these facts, it is readily apparent that an attempt to measure the pitch diameter of threaded products (other than precision gages) by the three-wire system is absolutely fallacious due to the fact that there may be and usually are inaccuracies in pitch and lead of such magnitude that would result in measurements which would be totally unreliable.

A pitch deviation of 0.001 would result in a pitch diameter deviation of 0.0017, plus or minus depending on short or long pitch, which is practically the total pitch diameter tolerance in many cases.

In the following the "Cone and Vee" may be rolls in a gage or a comparator, a pitch micrometer, knife edges, or the projection of thread profile on an optical chart.

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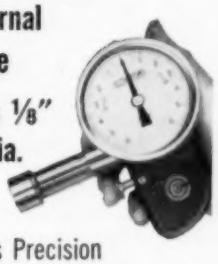

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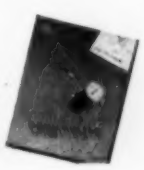

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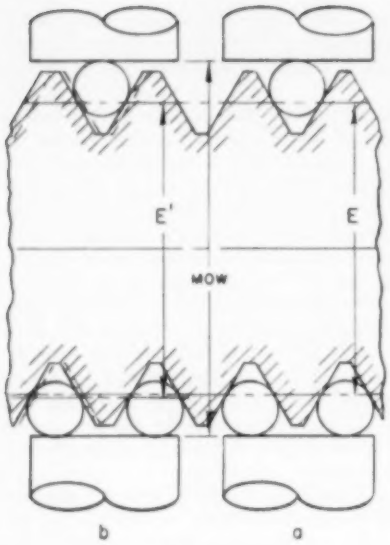

Figure 3

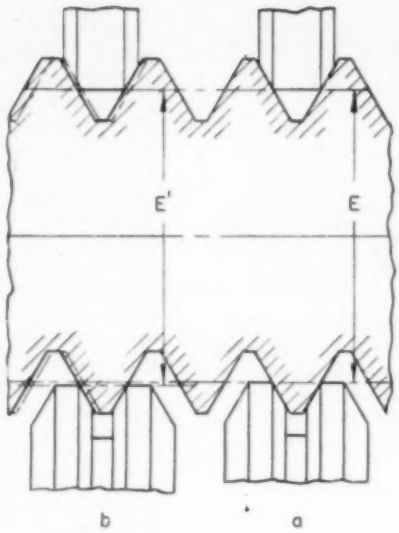

Figure 4

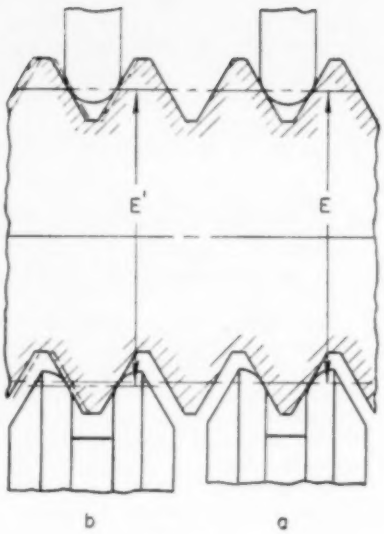

Figure 5

The "three-wires" may be the three-wire system, or rolls, or ball points in a gage or comparator made to the best-wire size which contact the "width of the spaces" only.

Figure 3-a shows the application of the three-wire system to a screw thread of correct pitch.

Figure 3-b shows similar application in which the pitch is incorrect. In both the wire readings "MOW" are identical even though the pitch diameter has increased from "E" and "E' ".

Figure 4-a shows the application of the Cone and Vee measurement to a screw thread of perfect pitch with the resulting pitch diameter measurement "E".

Figure 4-b shows the same application of Cone and Vee but to a screw thread with pitch error. The resulting pitch diameter measurement is "E' ". "E' " is obviously greater than "E" and reflects this variation because of the variation of pitch in Fig. 4-a and 4-b.

Figure 5-a and 5-b show the application of best-wire size radius rolls which are similar to the Cone and Vee type in Fig. 4-a and 4-b except that they have radius or point contact at the pitch line instead of flank contact. Both Cone and Vee types of rolls are identical in principle. The pitch diameter measurement in 5-a is "E" and in 5-b "E' ".

The obvious conclusion is that the three-wire system or best-wire size radius rolls type of measurement violates the basic concept of pitch diameter definition because of the fact that only the "width of the spaces" (material removed) is considered and the "width of the threads" (material remaining) is ignored. The screw thread being checked or the rolls or wires are free to float axially and thus seat themselves in the thread spaces.

On the other hand, the Cone and Vee combination fulfills the theoretical and practical pitch diameter check completely as the Cone seats itself in the "width of the space" while the Vee straddles the "width of the thread", resulting in a pitch diameter measurement that has taken into consideration both the "width of the space" and the "width of the thread" thereby incorporating any deviation from true pitch which may be present in the product being checked.

To carry the application of the Cone and Vee method to its ultimate would require a dual set-up, one with Cone contacts for the "width of the spaces" only and the other with Vee contacts for the "width of the threads" only. With each of these units set to a correct master thread plug, the reading on one comparator would give the diameter reading considering the "width of the spaces" only and the second comparator would give the diameter reading considering the "width of the threads" only. The true pitch diameter measurement would be the mean reading of the two. However, com-

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bining both the Cone and Vee in a single unit is adequate for practical purposes as it incorporates both the "width of the space" and the "width of the thread" into the measurement.

The three-wire system does not reflect accurately the movement of "the imaginary cylinder which passes through the several points at which the width of the threads and the width of the spaces are equal" unless the pitch of the screw being measured is perfect.

Conversely the Cone and Vee method does check "the imaginary cylinder which passes through the several points at which the width of the threads and the width of the spaces are equal."

The theoretically correct and practically sound principles of the Cone and Vee method must prevail over the three-wire system which ignores the "width of the thread" if true pitch diameter checking is to be obtained.

In conclusion, the three-wire system can measure true pitch diameter only when the pitch of the screw thread being checked is perfect or when the pitch is accurately measured and the deviation from perfect pitch is made a factor in the calculation for the three-wire measurement.

BOOK REVIEWS

W. D. Baten, Editor

26 University Drive, East Lansing, Mich.

STATISTICAL METHODS IN EXPERIMENTATION by Oliver L. Lacey, The MacMillan Company, New York, 2nd. Printing, 1957, price $5.25. Reviewed by J. G. Ripstra, American Seating Company.

A textbook designed for a one-semester course in general statistics as applied to experimentation that is ideal for the man in industry who wishes to teach himself the fundamentals of statistics in experimentation.

The author's claim in the preface that one semester of college algebra is sufficient and that an intelligent student with eighth grade arithmetic should do well with assistance, is optimistic as far as it concerns the student who attempts to use this book as a self instruction manual. It is not a cookbook and is written to give a full understanding of the elementary techniques in experimentation.

Chapter 9 on Test of Significance of Means and Differences between Means, Chapter 11 on Correlation and Chapter 12 on Regression are particularly valuable to the self taught student. The explanation of the solving of the Chi-Square problems in Chapter 10—Enumeration Data is easily understandable.

This book is a valuable addition to the plant library for use in training personnel entering the field of statistics, and as a handbook for the person who finds it necessary to use these techniques only occasionally.

SELECTED PAPERS IN STATISTICS AND PROBABILITY by Abraham Wald, Stanford University Press, Stanford, California, 695 pages, price $10.00. Reviewed by F. E. Satterthwaite, Statistical Engineering Institute and Merrimack College.

On December 13, 1950, Abraham Wald met his sudden and untimely death. During his relatively brief period as a statistician, he made prolific contributions to the field; probably no other person had such an impact on mathematical statistics during the 1940 decade.

This useful and important memorial volume opens with a one page biography. The only important criticism that can be made of this volume is that more biographical material is not given. The 28 pages of material by J. Wolfowitz, Karl Menger, and G. Tintner in the March 1952 (Wald Memorial) volume of the *Annals of Mathematical Statistics* could very appropriately have been reprinted.

The 18 page discussion of Wald's papers is well written. It is helpful to the reader in gaining a perspective of Wald's contributions as a whole and in identifying the contributions of special interest.

Wald's complete bibliography numbers 104 items, two-thirds of which appeared in the last 12 years before his death at age 48. Fifty-one of these papers have been selected for reprinting in full in this volume. They cover "most of Wald's research in statistics and probability except for work included in the books under his authorship," *Sequential Analysis* and *Statistical Decision Functions*.

Wald's work has, of course, had a major impact on quality control and statistical engineering. His was the first comprehensive study of the mathematical problems of sequential procedures. This is the foundation of our sequential sampling in quality control and is due for further application as we move strongly in the direction of sequential experimentation.

As statistical engineering graduates to dealing with more sophisticated problems, Wald's basic works will become more and more important. Wald's main work is a unified theory of decision based on such ideas as loss, cost and risk functions, the minimax principle, Hayes solutions, and the "least favorable" prior assumptions. Here is the first realization that these ideas can be used to construct a unified general theory of statistics and, equally important, that they provide tools for solving explicit problems.

Besides contributions to probability, particularly in connection with moments, limits, and cumulative sums, Wald took an early interest in the development of non-parametric methods with proposals of important new techniques and for evaluation of the performance of specific procedures. His paper on the two-sample test is a classic in this area. Papers on non-parametric tolerance limits will become of increasing interest in engineering statistics

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as we get into problems where distribution assumptions are dangerous. With the trend to variance component analysis, Wald's papers on confidence limits of variance ratios is another important foundation tool. His work on difference equations will become more important as we move away from linear and Taylor's series models to study the differential equations controlling the phenomenon being studied. Regression analysis with both variables subject to error was thought to be an unsolvable problem until Wald showed the way. There is also an important paper on the theory of continuous sampling inspection plans.

Wald made many contributions to the theory of testing of hypothesis and estimation, particularly in connection with devising definitions of the optimum performance of tests by means of power functions.

Most of Wald's papers are not easy reading for those without training in pure mathematics. Here was a pure mathematician of the highest order with a keen sense of the practical and the important. From such a mind comes foundations that will influence statistical developments for many years.

What's New?

ROY A. WYLIE, *Editor*

When inquiring about "What's New?" items, please mention INDUSTRIAL QUALITY CONTROL

The Sheffield Corp., Dayton 1, Ohio, has announced the Eli Whitney Unipoint Internal Measuring Instrument, a new electronic hole checker that measures bores for size and taper down to 0.043 inches (approximate size of a typewritten period) and up to 1⅜ inches. The gage also detects bellmouth, hourglass and out-of-round conditions. The precision capability of this instrument in small hole measurement is such as to demand its use under controlled environmental conditions. As a result, it is used for certified calibration of Master Ring gages, precision parts, internal grooves and ball races. The gage consists of a bench-type workholding table and a special electronic Accutron amplifier. The gage has but one gaging contact instead of two fingers or styli found in other internal measuring instruments. The single gaging finger has a vertical adjustment up to one inch, and gaging pressure is less than three grams. The Unipoint Hole Checker needs no parallels or rolls for set-up. The gaging stylus has longer wear life because it can be rotated. Five interchangeable styli cover the full gaging range. Gaging information is picked up from the reed-mounted stylus by an Electrojet gage cartridge and transmitted to the electronic Accutron Amplifier having two-range dual amplification up to 20,000 or 40,000 to 1.

★ ★ ★

A new interchangeable direct reading attachment for a high resolution spectrograph is available, from **Baird-Atomic, Inc.**, 33 University Road, Cambridge 38, Mass. The attachment for the 3-meter Grating Spectrograph permits this analytical instrument to be used for routine quality control as well as research studies, providing fast accurate dial readout analyses on the routine samples, while allowing for rapid changeover to the unlimited range possible with spectrography. The direct reading attachment presents, as percent concentration, readout of eight elements in less than two minutes with precision and freedom from human error. The attachment features the automatic Servo Monitor for constant, precise optical alignment and compensates for environmental variations. Until now, optical stabilization problems have prevented the combination of direct reading facilities with the spectrograph. For more than five years the B-A Automatic Optical Servo Monitor used in Direct Reading Laboratories has proved that the position of spectrum lines can be maintained to two or three microns. This monitor, now incorporated into the Direct Reading Attachment, corrects angular deviations of less than ¼ second of arc. A new electronic slit setting attachment of unequaled accuracy, permits the Direct Reading Attachment to be realigned to eight different elements in less than one hour. The Phototube Assembly which translates the spectral image intensity to a dial readout is rapidly interchangeable with the 3-meter spectrograph standard 20 inch camera.

★ ★ ★

The Industrial Test Equipment Co. of 55 E. 11 St., New York 3, N. Y., has developed a new model of the versatile Phazor Phase Meter. Designated Phase Meter Model 200 AB, the instrument features high sensitivity, and high input impedance for the reference input as well as for the signal input. As with the other Phazor instruments, the Model 200-AB measures phase angles by a unique multiplying principle which permits measurements to be made accurately in the presence of noise and harmonic voltages. The instrument can be used to measure in-

phase and quadrature components of voltage, and by the use of simple circuit techniques may be used to measure phase angles in the order of 0.01 degrees. The unit can be supplied in a portable type cabinet or with a 19 inch panel for rack mounting. Some outstanding features of this instrument are:

1. Self calibrating action assures high accuracy
2. Measures from 0 to 360 degrees without ambiguity
3. Readings not affected by noise or harmonics
4. High sensitivity on both reference and input channels
5. Wide input voltage range
6. Broad frequency range
7. Electronic limiting to prevent instrument overload

★ ★ ★

Faster and more accurate chemical analysis of labeled compounds is now possible, through the use of a new paper chromatograph scanner developed by **Nuclear Measurements Corp.**, 2460 N. Arlington Ave., Indianapolis 18, Ind. Of primary use to chemists and biologists in the analysis of C-14 and other soft beta emitting compounds, the instrument also has wide application in biochemical analysis. It detects beta-gama emitting isotopes such as C-14, S-35 and P-32, and when operated as a proportional counter also senses alpha radiation. Either strip or two-dimensional chromatographs are handled automatically. The scanner incorporates in one integrated automatic system a detector, scaler, recorder and scanning mechanism. Once started, the unit completes the scanning operation automatically and then turns itself off. A variety of traverse distances and scanning rates provide wide operating flexibility.

★ ★ ★

A new low-cost Flatness Tester, permitting unskilled labor to run tests with maximum efficiency, has been introduced by **Gits Brothers Mfg. Co.**, 1866 South Kilbourn Avenue, Chicago, Ill. The Flatness Tester is a fast, accurate device for determining degree of flatness or conformity for matching two pieces. Tests to reveal surface fissures, or to gage lapped surfaces and ground surfaces can also be made with this equipment. The unit was designed to test individual parts or small assemblies, including face type shaft seals, metal seating valves of all types, aircraft parts, magneto parts, governors and carburetor parts, automotive parts, "O" ring grooves. The Gits Flatness Tester can often be substituted as a production device, wherever optical flats are used. In surface testing, it eliminates the need for the costly, time-consuming water immersion method. Small and compact, the unit comprises a vacuum pump and instrument panel with an attached testing plate. The testing plate can be custom engineered in size, shape or material for applications of any type. In most cases clamping fixtures are not necessary since the vacuum pull acts as a sealing force. The Flatness Tester combines an ultra sensitive pressure differential sensing device with a reliable electronic timing circuit to provide a gaging instrument which repeats with absolute uniformity regardless of parts tested.

RUTGERS ADVANCED CONFERENCE

A six-day advanced conference series on "Applied Statistics and Statistical Quality Control" will be offered Sept. 3-10. This advanced course is designed to provide additional instruction for persons who have had both a basic course and industrial experience in the SQC field.

It will include advanced topics in SQC such as sampling by variables, tests of significance, narrow limit gages in process control, sampling in chemical processes, practical designs of experiments, "trouble-shooting" in production, correlation and regression, management aspects of a quality control program. Familiar techniques will be extended and new ones presented to provide an integrated approach to industrial problems. Individual industry interests are served by providing laboratory sections grouped by area-interest; especially chemical, electrical, mechanical and advanced statistical techniques.

The full-time Rutgers staff members who will be associated with this advanced conference are: Professors Ellis R. Ott, Harold F. Dodge, and Mason E. Wescott. Special lecturers will include: J. Stuart Hunter, Enoch B. Ferrell, Allen R. Crawford, Richard S. Bingham, A. B. Mundel, Paul S. Olmstead, and David S. Chambers.

Tuition is $150 which includes text and instructional material. For additional information, write to Professor Ellis R. Ott, or Professor Mason E. Wescott, Rutgers University, New Brunswick, N. J.

CONSTITUTIONAL AMENDMENTS APPROVED

At the Annual Meeting of the Society, Monday afternoon, May 28, the Tellers Committee announced that all the proposed constitutional amendments were passed by the required majority of the votes of the membership.

These new amendments include the addition of two new grades of membership—associate member and enrolled student. With these new grades and the higher requirements also passed for admission and advancement to the corporate grades of membership, the Society has greatly improved its position in the direction of professionalism. These changes will help place ASQC on a level with the other professional societies.

In addition to these important changes, the new membership dues amendment was also approved. The basic annual dues for the fiscal year beginning July 1, 1958 are now:

Enrolled Student	$ 3.00
Associate Member	10.00
Member	12.00
Senior and Fellow	15.00

All current billing is being made on this basis.

A new service to aid industry with fastener fit and thread problems has been announced by **Standard Pressed Steel Co.**, Jenkintown, Pa. A series of three screw thread metrology laboratories have been completed at the Jenkintown, Pa. headquarters, at the Cleveland plant of the subsidiary, The Cleveland Cap Screw Company, and at SPS Western in Santa Ana, Calif. The purpose of the laboratories is to help industry meet steadily increasing demands for mechanical precision and to reduce production losses resulting from fastener assembly problems. Equipment and techniques available at the SPS Screw Thread Metrology Labs for untangling thread problems will be similar to those developed and used successfully by SPS in dimensional control of its own precision fasteners. Some of the precision measuring machines will check critical thread dimensions to the nearest millionth of an inch. The laboratories will be completely equipped for thread size control of Classes 3A, 3B, 2A and 2B screw threads and of ANPT and NPTF types of tapered threads. Each lab is equipped to measure all screw thread elements—diameters, angles, lead, radii and others; to check and if needed, set related thread gages and set masters; and even to run close dimensional checks of the possibly faulty threading tools, themselves.

★ ★ ★

The **Micrometrical Manufacturing Co.**, 345 South Main Street, Ann Arbor, Mich., has announced the addition of the vertical Wavometer to the Micrometrical family of precision measuring instruments. The Wavometer is an instrument for measuring waviness on symmetrical surfaces of rotation. The new unit will handle ID's and OD's of surfaces up to 18 inches in diameter, and provides for angular adjustments of 30 degrees above horizontal to 70 degrees below. The Wavometer is simple to operate, requiring no technical knowledge or special skill. The Wavometer gives meter readings of the R.M.S. average height of the waves in two wave bands, directly in microinches. In addition, an oscilloscope shows the general shape and spacing of the waves in either waveband. A loudspeaker transforms the surface irregularities into sounds, and deviations from the normal are easily detected by the operator. The Wavometer shows the effects of finishing processes on waviness, and what is accomplished by steps taken to obtain a less wavy surface thru changes in production operations. It also provides for measuring work in the inspection and production departments, permitting unsatisfactory parts to be identified and set aside before they are finished or assembled.

Spanish Quality Control Study Group Reviews U. S. QC Methods

A Spanish Quality Control Study Group, under the guidance of the Council for International Progress in Management, during April visited several cities and reviewed American methods in quality control and industrial statistical applications. Arrangements for the visit were made through the cooperation of the Society.

The Cincinnati section was host to the group during the week of April 7-11. Bill Barker, section chairman, arranged four plant visits and an evening reception for the touring industrialists and engineers.

A reception was held at the Hotel Sheraton-Gibson, and the featured address was given by Leon Bass, ASQC President and Quality Control Manager of General Electric's Jet Engine Department at Evendale. The Spanish men were given an instantaneous translation through an interpreter, and a closed-circuit amplifier with individual earphones. A great deal of interest was shown in Mr. Bass' talk on how the Spanish industries could benefit from increased productivity and improved quality. An interview was arranged with a reporter from the *Cincinnati Enquirer*, and a featured article appeared in the newspaper on Friday, April 11.

The industries visited by the Group were: Nutone, Inc., The Formica Division of American Cyanamid Co., Champion Paper and Fibre Co., and the Kroger Food Products Plant. These four southwestern Ohio industries showed and demonstrated their quality control techniques and practices in all-day plant tours.

The Spanish Team, ranging from a university professor to a technical director and purchasing chief in a pharmaceutical plant, was particularly impressed with the practical approach to quality control that it saw in the plants visited.

Demonstrations in statistical and quality control methods were given at the Gibson reception following Mr. Bass' speech. A demonstration in median-range charts was given by J. S. Gantt; a discussion of number defective tables and pyramidal reporting was given by Mr. Barker; and an insight into experimental design and analysis was given by M. J. Bratt. These men, all of the Cincinnati section, are from the Quality Engineering Unit at General Electric's Jet Engine Department.

Members of the Cincinnati section's executive committee present were:

D. A. Brandt	Vice Chairman
Harry Brennan	Secretary
Ada Diehl	Treasurer
Dick M. Race	Saddoris Award Chairman

Quality managers James Christy from Nutone and Robert Johnson from Kroger also were present.

New Literature Available

A 102-page 34th Anniversary catalogue has been published by Gardner Laboratory, Inc., P.O. Box 5728, Bethesda 14, Md. In the catalog are descriptions, illustrations and price lists covering a complete line of testing instruments for paint, paper, plastics, ceramics, food, leather, oil, rubber and other materials.

An up-to-date description of the Coleman Electronic Photofluorometer, Model 12C, which is used for the accurate measurement of Vitamins, Quinine, Atabrine, Flourescein, Porphyrins, Steroids, Catecholamines, metal complexes and other compounds measurable by fluorescence, is available from Coleman Instruments, Inc., 318 W. Madison Street, Maywood, Ill.

Rese Engineering, Inc., 731 Arch Street, Philadelphia 6, Pa., has made available a two page bulletin number 57-E describing the use of Models 4021 and 4022 Manual Core Test Jigs for testing and analysis of metallic tape-wound and miniature ferrite magnetic memory cores. Each model is illustrated and a circuit diagram and complete specifications are included.

Catalog No. 175 published by the Pyrometer Instrument Co., Inc., Bergenfield, N. J. includes descriptive and technical data on the PYRO Op-

tical, Micro-Optical, Radiation, Immersion, Surface and Indicating Pyrometers.

Concise information about the Electro-Chemograph equipment for polarographic measurements, an instrument now used in many industrial and research organizations, is available in a new 4-page data sheet just published by the Leeds and Northrup Co., 4934 Stenton Ave., Philadelphia 44, Pa. Many convenient features of the Electro-Chemograph are illustrated in the new data sheet, including a recorder with a full-scale balancing time of only one second, a built-in standardizing cell, and a newly designed, compact Polarotron dropping mercury assembly.

Where and how to use Plunjet air gaging cartridges in single and multiple dimension gages and inspection fixtures is described and illustrated in a new 32-page publication from The Sheffield Corp., Dayton 1, Ohio. Plunjets are pneumatic size-sensing pickup units for use with Sheffield Precisionaire gages and other types of air gages.

Low-cost Beckman Infrared Spectrophotometers for routine laboratory qualitative and quantitative analyses are described and illustrated in a new infrared brochure, Bulletin 724 published by Scientific Instruments Division, Beckman Instrument Inc., 2500 Fullerton Road, Fullerton, Calif.

section briefs

ALBANY . . . "Vendor quality rating" was discussed by H. G. Harding of the IBM Corp. at the April meeting. Robert Mapes, Behr-Manning Corp., was moderator for the afternoon problem session. He reviewed the application of several useful statistical techniques.

Ed Bauer has been elected section president for the new year. Other officers are: Don Holmes, vice president; Paul J. Paniszczyn, treasurer; and Mel Lindquist, secretary.

On Apr. 17 the section, with TAPPI, co-sponsored a conference on quality control. The conference was held in Glens Falls, N. Y.

ALBUQUERQUE . . . The April meeting featured a series of short talks by speakers from the Sandia Corp. T. D. Harrison, a manufacturing engineer, spoke on "The practical application of quality control." He discussed several actual situations involving the use of quality control techniques. C. R. Clark and Dr. B. Ostle, statisticians in the reliability department discussed "The extension of Dodge's chain sampling plan" and "Acceptance sampling based on the distribution of the range of a triangular distribution." Refreshments and a "bull session" followed the regular meeting.

ALLENTOWN-BETHLEHEM . . . The April meeting was our annual joint meeting with ASTE held at the Hotel Traylor. The combined groups heard Dr. Gayle McElrath of the University of Minnesota discuss the reasons for designing experiments. Many new jokes were learned and even the dinner was good. Well, that's the way the mop flops.

BALTIMORE . . . Dr. George Vlases, Jr., chief of the division of technical services of the Bureau of Customs, presented a very interesting talk on the use of statistics in sampling and weighing imported bulk materials handled by the Bureau of Customs. A number of practical applications were discussed and written descriptions of these were distributed to the good sized audience which attended the meeting. A lively discussion period, featured by refreshments, followed the meeting.

BATTLE CREEK-KALAMAZOO . . . On Apr. 16 Dr. Aubrey Wylie, Department of Forest Products of Michigan State University, spoke on the subject "Modern quality control in an old industry." Dr. Wylie's talk concerned itself with quality control in the wood industry. The talk was very well received by the group. This meeting was held on the campus at Michigan State University.

BINGHAMTON . . . The following officers have been elected for the 1958 season: chairman—J. A. Jirauch, vice-chairman—D. L. Moses, secretary—S. M. Rogge, and treasurer—H. G. Salisbury.

C. H. Rubin has been informed that the section is the winner of the Saddoris Award for Section Management for 1957.

BOSTON . . . An all-day seminar was held on Mar. 31. The theme of the seminar was "Latest developments in quality control."

BUZZARDS BAY . . . Allen R. Crawford, Esso Research and Engineering Co., Elizabeth, N. J., discussed "Design and analysis of industrial experiments" at the Apr. 8 meeting held at the Continental Screw Co. He demonstrated how statistical methods can provide effective guidance in planning experiments which give desired information with minimum effort. Typical case studies of the solution of complex problems encountered by the research worker as well as the production engineer were cited. Illustrations using classical designs, Latin squares, and factorial designs were made exciting by the speaker and created a lively question period. Members and guests attended from New Bedford, Fall River, and Taunton. Kenneth E. Bennett of Revere Copper and Brass Co., section chairman, presided at the business session. New officers elected for the coming season were introduced. A schedule of meeting dates and program plans for the coming season were announced.

CHARLESTON . . . The section enjoyed the exhibit and demonstration of working models (gadgets for quality control as he called them) arranged by Wallace Kellog and his committee at our April meeting. Fortunately, each demonstration stayed "within control" and the demonstrators were not called upon to explain the **usual** occurrence to a number of guests of the section.

The executive committee enjoyed their meeting with Dave Birch, district 8 director. Because of his tight schedule, the meeting was a luncheon and between bites the committee was given considerable information about the Society and the proposed amendments to the constitution. More active support of the amendments by the committee and the section will result from Dave's visit.

CHATTANOOGA . . . The following officers were elected for the coming year at the April meeting: chairman—B. F. Kennedy, vice chairman—P. S. Deck, secretary—J. C. Hornsby, and treasurer—S. F. Torbett.

CINCINNATI . . . From Apr. 7-11 our section was host to a group of Spanish industrialists touring the country to observe American QC methods. They were shown through several Cincinnati industries—Formica, Nutone, and the Kroger Co.—and were entertained at a reception held Apr. 10 at the Sheraton-Gibson Hotel. Quality control managers Wes Carter of Formica, Jim Christy of Nutone, and Bob Johnson of Kroger, did a fine job of arranging the plant tours for the group. On Apr. 9 the group visited the Champion Paper & Fibre Co., Hamilton, with Gordon Thompson as host. In the evening they attended the regular monthly dinner meeting of the Hamilton-Middletown section.

The three-course spring education program is now history. Each person who completed the course received a certificate at the May 21 meeting.

CORNING-ELMIRA . . . Sincere thanks from the entire section are extended to Frank Caplan for his fine talk on "Process control in a job shop."

CUMBERLAND . . . Richard S. Bingham, Jr., the supervising engineer of the quality control branch of The Carborundum Co., was speaker at the Apr. 1 meeting. His topic, "Control charts in multi-stage batch processes," provoked a lively discussion which was enjoyed by all.

EVANSVILLE-OWENSBORO . . . On Apr. 15 the section enjoyed a tour of the Igleheart Bros. plant, home of Swans Down flour and cake mix. Harvey Bower discussed quality control procedures at the plant prior to the tour. Each member making the tour was presented with a wonderful gift of cake mix and cake pans.

GREATER MUSKEGON . . . Thirty-five members and guests toured the facilities of the Keller Tool Co., Grand Haven, on Apr. 10. The plant visitation was preceded by a dinner at the Spring Lake Country Club. Summit managerial officers extended a welcome to the group. John Welch, quality control supervisor of Keller's, served as tour coordinator.

The program committee is considering having either a family beach roast or an outing at the Spring Lake Country

LANSDALE SECTION

Club during the summer months. Previous practice has been the absence of any meetings from May to September.

HAMILTON . . . Our section is deeply grateful to Society President Leon Bass for his attendance at the Apr. 17 meeting held at Fischer's Hotel. In addition to delivering a very interesting paper on "Vendor certification," Mr. Bass also brought us up to date on the proposed amendments to the constitution.

HARRISBURG . . . On May 7, the section met at the Grandview Country Club in York. Dr. Milton Sobel of the Bell Telephone Laboratories spoke on the subject "Ranking and selecting problems."

The new officers for 1958-59 are: chairman—Steve Combs, vice chairman—George Thomas, secretary—Betty Bell, and treasurer—A. B. Brown.

HUNTSVILLE . . . Samuel Patton, inspection supervisor at Wolverine Tube, spoke on "How to make an investigation" at the April meeting. The newly elected 1958-59 officers were also announced.

KANSAS CITY . . . The April meeting was held in the plant of the Vendo Company, manufacturers of vending machines. Dinner was explained as a practical experiment for "customer" reations to in-plant-feeding. A complete meal was available from vending machines arranged in a line against a backdrop of old Western store fronts labeled "The Corral". Following a short business meeting which included the announcement of elected officers for the coming year, members and their guests were conducted on a plant tour with special emphasis on quality control activities of the company.

LANSDALE . . . The Apr. 10 meeting found the members of the Lansdale section at Superior Tube Co., Collegeville. The first chairman of the section, Harry Poole who is director of QC for Superior Tool, was speaker for the evening. (The photo at the left shows section chairman Charles G. Weidmann, right, helping Mr. Poole with an experiment in probability.) Mr. Poole's talk on the subject "A glimpse at the quality control course as conducted at Superior Tube" was very well received by the members. A buffet supper followed.

LOS ANGELES . . . The Apr. 15 meeting was handled by E. C. (Bob) Bennett and an all Northrup Aircraft panel. "Optimizing quality effort in the machine shop" was well taken up by Mr. Bennett and the panel as they covered the management, production, application, and statistical phases.

"Statistical pitfalls in industrial experiment" was the topic at the May 13 meeting. Dr. Louis B. Kahn of the Shell Development Co. explained some of the precautions that should be taken in experimental and development work. Eighteen new members were announced.

LOUISVILLE . . . Dr. Charles R. Hicks, associate professor of mathematics and statistics at Purdue University, gave a most interesting and stimulating presentation, entitled "Quality control in short run production" at the monthly meeting on Apr. 14. The meeting was preceded by a social hour and dinner in the dining room of Ballarmine College.

MEMPHIS . . . Frank Caplan, Jr., assistant manager of quality control, Atomic Fuel Dept., Westinghouse Electric Corp., Cheswick, Pa., gave an enjoyable talk on "Incoming inspection and vendor relations" at the Apr. 4 meeting.

The May 2 meeting was addressed by Paul K. Leatherman of Mallinckrodt Chemical Works of St. Louis. Mr. Leatherman's subject was "Can a vendor be rated."

METROPOLITAN . . . The section conducted its first Buzz Session on Apr. 17. The session was conducted by splitting the audience into nine groups by industry and discussing several controversial topics. Harry D. Greiner, quality control manager for the Jet Engine Division of the Budd Company, was keynote speaker. For a period of 20 minutes preceding table discussions, Mr. Greiner discussed various areas in which quality control operates. The discussion was then turned over to those attending the meeting and discussion was centered on the following two topics:

a) Should Quality Control be empowered to shut down machines?

b) Should Quality Control approve sources of Supply?

The discussion period lasted for about 45 minutes and was followed by a coffee break. During this period the keynote speaker received comments from each of the table group leaders and after coffee, presented an over all summary of the audience opinion. The concensus of opinion of the group, which consisted to some extent of people in production, was that quality control should not be empowered to shut down machines but that they do have the responsibility of advising the production foreman that the machine is producing defective material and should be shut down.

Regarding the matter of quality control's responsibility in approving sources of supply, the general feeling was that quality control is responsible for a vendor rating program and also for advising the purchasing department of vendors' quality. There is an increasing tendancy to bill the purchasing department for additional work required on substandard material so that the purchasing department will then have some justification in deciding to place orders with slightly higher priced vendors who supply better quality products. There was also a strong feeling that representatives of quality control should participate in surveillance conducted in the vendors' plants prior to placing orders.

A questionnaire handed out at the meeting indicated an overwhelming desire on the part of those attending to have more discussions of this type and to increase the length of the discussion period. We highly recommend that this kind of meeting be tried in other sections. It was our first attempt and we will run similar sessions during the forthcoming year due to its great success.

MID-HUDSON . . . A joint meeting with ASTE was held Apr. 1 with 60 members and guests attending. Guest speaker was John W. Sullivan, metallurgical engineer for the American Steel Institute of New York city. His topic, "Statistical methods in steel technology," was well received by the combined group.

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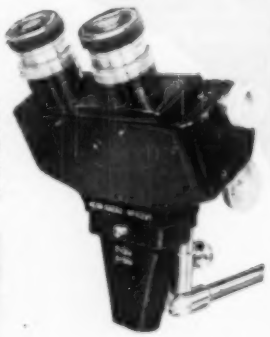

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An executive board meeting was held Apr. 15 to review the past year's activities and formulate committee structure for the coming year.

MILWAUKEE . . . There was a nice turnout at the Hotel Stratford on Apr. 21 to hear W. W. Kauffman, manager of quality coordination for the RCA Defense Div. He discussed the approach taken by the division in setting up quality control—extending from the time of contract negotiation through design, procurement, manufacturing, assembly, test packing, shipping installation and management in field use. He indicated some of the areas of concern to the QC manager and pointed out some of the techniques employed in achieving and attaining the high level of quality required in military electronics.

The last two educational sessions for the season were held just prior to the meeting. The subjects were "Analysis of variance part II" and "No calc variables acceptance plan."

MINNESOTA . . . The field trip to the IBM Rochester plan was very successful. In addition to an interesting tour, there were several speakers from various phases of IBM management. A random sample of the participants indicated that the meal was "terrific."

MONTREAL . . . On Apr. 16 August B. Mundel of the Sonotone Corp. spoke on "Quality control in the electronics industry." This was a joint meeting with IRE and judging from the question and answer period Mr. Mundel's talk was well received by everyone present.

NEW HAVEN . . . G. R. Scheel, assistant director of quality control and inspection for the Sonotone Corp., White Plains, N. Y., presented a very informative program on the control of phonograph cartridge quality at Sonotone. The program, held at the Winchester Club House, followed a business meeting which included election of officers for 1958-59.

NORTHEASTERN INDIANA . . . On Apr. 10 at the Chamber of Commerce in Fort Wayne, the section held its regular monthly meeting. The membership and guests present heard a very timely, interesting, and informative speech given by William B. Courtwright, director of quality control, Argus Camera Works, Ann Arbor, Mich. His subject was "Inventory valuation by sampling."

OMAHA-LINCOLN . . . Twenty-five members and guests attended the Apr. 11 meeting held at the Capitol Hotel in Lincoln. Dr. Irvin L. Reis spoke on "Acceptance sampling by variables."

PITTSBURGH . . . The Apr. 22 meeting was an interesting tour of the Homestead plant of the Continental Can Co. The tour included demonstration of lithographic printing of the tin plate prior to the making of the can as well as showing the manufacture of cans, crowns, and caps. Liberal use is made of QC charts throughout the plant. The tour also included the laboratories where incoming raw materials and outgoing containers are tested. The plant tour was arranged by John De Canio, the division resident inspector.

During the two week period Apr. 14-25 the section took over two classes in the special "Automation in industry" course given at Allegheny High School to a select group of high school seniors from the entire Pittsburgh area. The course was taught by seven members of the section and consisted of ten two-hour sessions for each class of about 30 students. The topics covered were gauging, frequency distributions, control charts, sampling plans, significance testing, and regression.

PITTSFIELD . . . An excellent talk was given by Society President Leon Bass, manager of quality control for General Electric's Jet Engine plant at Evendale, Ohio, to a joint meeting of the section and IRE. Mr. Bass spoke on the "Use of statistical methods for engineers." The talk was enlivened by the use of very effective slides and was followed by a lively question and answer period.

During the months of June and July, the newly elected officers will be given briefing and discussions at meetings to be held at the Stanley Club. The time of these meetings will be 7:30 - 10 pm on dates to be arranged. Activity for an exciting 1958-59 program is already well underway.

PORTLAND . . . John Ogden, United Airlines Maintenance Base at San Francisco, was guest speaker at the May meeting. Mr. Ogden gave a well prepared and interesting talk devoted to the functions of quality control techniques applied to the maintenance of aircraft. The new offices of the Pacific Materials and Readymix Concrete Co. served as headquarters for the meeting. Guests were welcome and coffee and refreshments were served.

ROCHESTER . . . Recent meetings were addressed by A. C. Rosander of the U. S. Treasury Department and Prof. Gayle W. McElrath of the University of Minnesota.

Section member John M. Allderige, operations research consultant of the Eastman Kodak Co., addressed the Apr.

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16 meeting of the National Association of Accountants which was held at the Manger Hotel.

Newly elected officers for 1958-59 are: president—William H. Harrison, Bausch & Lomb Optical Co.; vice president—W. Carl Jensen, Haloid-Xerox, Inc.; secretary—Wilbur C. Myers, Delco Appliance Div., GMC; and treasurer—Thomas J. Soebbing, Eastman Kodak Co.

ST. LOUIS . . . At the Apr. 18 meeting the following officers were elected; president—Samuel H. Huston, vice president—Simon D. Krasner, secretary—E. Harvey Barnett, and treasurer—Boris Miller.

Diplomas were awarded to 25 students for completing the training course.

The annual student award was presented to Edward Wintergallen of St. Louis University for his paper on "Attribute sampling plans for continuous production."

Les Eichleberger, Society Executive Secretary, attended this meeting and made a short talk to the members.

SAN ANTONIO . . . Robert Lusser, reliability coordinator of Redstone Arsenal, gave a very enlightening address to 40 members and guests on the subject "The notorious unreliability of complex equipment" at the Apr. 8 meeting. Mr. Lusser's presentation was very interesting and informative.

The following officers were elected at this meeting to serve for the 1958-59 year: Robert W. Worrick, San Antonio Air Material Area, chairman; Robert J. Weisbrod, SAAMA, vice chairman; John R. Gilpin, SAAMA, Treasurer; and Earl W. Doiron, SAAMA, secretary.

SAN BERNARDINO . . . The section met on Apr. 12 at Harolds Club for its regular monthly dinner meeting. Speaker for the evening was Fred Maston, specifications engineer, Cannon Electric Co., Los Angeles. Mr. Matson presented a very interesting subject "Dynamic controls for assured component quality" which was enjoyed by all.

SAN FRANCISCO BAY AREA . . . The May 12 meeting was held in the East Bay under the coordination of Allen Chop. Don Guthrie spoke on "Design of Experiments."

SEATTLE . . . The Sixth Pacific Northwest QC Conference, presented by the section, was held on Apr. 11-12. The conference committee assembled an extremely interesting program covering education, general applications, administrative applications, aircraft and other industries, and foods. Senator Henry M. Jackson was featured as the luncheon speaker. The conference was well attended by representatives from many Pacific Northwest industries.

SOUTH BEND-MISHAWAKA . . . "Machine capabilities written into purchase orders" was the title of the speech we were privileged to hear from Ben T. Bernacchi director of engineering of the American Safety Razor Co. Kingsbury Div. on Apr. 17. According to Mr. Bernacchi "Machine capability in the final engineering design for specialized equipment can only be accurately realized after the extensive use of statistical quality control methods" as he explained in detail how his engineers employed statistical methods in designing specialized shell-loading equipment.

SOUTHERN CONNECTICUT . . . On Apr. 9 R. Shaw Goldthwait, elder stateman of quality control in New England and director of quality control at Collyer Insulated Wire Co.,, was featured speaker. The meeting was held at LaNormandie in Westport. Mr. Goldthwait was an interesting speaker and his topic on "Quality control in the production of wire and cable" was well received by his audience.

SOUTH TEXAS . . . The section held its regular monthly dinner meeting in Baytown on Apr. 9. The speakers were Joe Dickson and A. R. Stark, who spoke on "Quality control at Humble." The meeting was preceded by a tour of the Baytown plant of the Humble Oil and Refining Co.

The results of the election of section officers for the coming year was announced. They are: chairman—R. M. Shappee, vice chairman—A. R. Stark, secretary—B. M. Appleman, and treasurer—O. L. Nordin.

The appointment of L. M. Buttery to serve as general chairman of the second annual all-day conference to be held in Houston in February 1959 was also announced.

TOLEDO . . . "Management's reactions to SQC in production" was the subject of C. G. Rittenhouse's discussion at the Apr. 3 meeting. Drawing from a wealth of personal experience, Mr. Rittenhouse presented several important considerations necessary for management to make in order to adequately decide upon the advisability of a given quality control program. One such consideration is dollar-saving. A most lively and interesting discussion period followed Mr. Rittenhouse's talk. Mr. Rittenhouse is assistant superintendent of the Cine and Sheet Film Division of the Eastman Kodak Co., Rochester.

The 1958-59 officers for the section are: David A. Hettel, Johnson-Ruth Machinery Co., chairman; Ward W. Wright, Dana Corp., vice chairman; Theodore R. Meyer, Kimble Glass Div. of Owens-Illinois, secretary; and Joseph A. Ivan, L-O-F Glass Fibers, treasurer.

TORONTO . . . On Apr. 9 the section enjoyed a very interesting and educational lecture given by Walter Pukalo, production engineer, Department of National Defense, inspection services, electrical engineering and electronics branch, Toronto. Mr. Pukalo covered the theoretical bases for three major sampling plans (Dodge-Romig, Columbia, and MIL-STD-105A) and explained the specific differences, especially with regard to producers' and consumers' risks.

A pleasant and informative evening was offered members of the section by the management of Anaconda American Brass Ltd., New Toronto. During the plant tour it was shown how, among others, the various alloys and metal hardnesses were kept within specifications by statistical control. An excellent buffet and liquid refreshments concluded this well spent evening.

WINDSOR . . . Management night, the final meeting of the 1957-58 season, was held on Apr. 16 at the Prince Edward Hotel. An overwhelming attendance of members and guests enjoyed a fine meal and an exceptional talk by Dorian Shainin, whose subject was "Controlling the quality of management decisions." Mr. Shainin is consultant on industrial statistics in the firm of Rath & Strong of Boston

JOSEPH J. LISY

The Chicago section and ASQC lost a staunch friend and a loyal member in the passing of Joe Lisy on May 7, 1958. Joe put in a normal day's work at his office May 6th, spent a normal evening at home with his family, went to bed as usual, and passed away in his sleep. He was just three weeks past his 58th birthday at the time of his death.

Joe was born and educated in Chicago. He graduated from Harrison Technical High School. He attended DePaul University for two years and Morton College for one year where he majored in accounting. He was quality control supervisor at Hot-Point from 1943-45, at which time he became auditor of distribution with the Division of Tax Collection Agency in Cook County. He held this position until 1957 when he was promoted to supervisor of the same agency, the position he held at the time of his death.

There are unsung heroes in every organization. Joe was one of these. He shunned personal publicity, but never shirked an opportunity to serve with quiet, unassuming fidelity wherever and whenever his help was needed in the activities of the Chicago section. Although not employed in the manufacturing field, he was a firm supporter of the objectives of ASQC and took an active part in the business management of the Chicago section.

Joe, a senior member of the Society, joined the Chicago section in 1946. He was treasurer of this section for many years, and subsequently chairman of its Auditing Committee until his death. He was a Director of the section for several terms. For seven years he carried the burden of making all arrangements for the annual two-day training program sponsored by this section in cooperation with the Chicago Chamber of Commerce.

Joe is survived by his mother, Alz Lisy Strohmayer, his daughter, Rosemary, and his son Donald.

Funeral services were held Saturday, May 10th.

Those who knew and worked with Joe will mourn his passing and remember him with affection and respect for the warmth and sincerity of his friendliness and the calibre and loyalty of his service to the sound management and growth of the Chicago section.

and is an award winner in the Society. His competence in handling such a difficult topic resulted in a successful climax to our season's program.

WINNEBAGO . . . On Apr. 14 a one-day QC clinic was held at the Beaumont Hotel, Green Bay. The general chairman for the event was Leland J. Manders, Charmin Paper Products. The clinic was a success both from the caliber of the program presented and financially as well. The success of the clinic was due to the whole hearted support of the members who worked and put forth their own effort to make it the success it was.

SIGNIFICANT DIFFERENCES

. . . Albuquerque—L. J. Paddison of Sandia Corp., formerly director of quality assurance, is now the director of reliability development.

Dr. J. H. Findlay, Sandia Corp., was recently promoted to director of quality assurance.

. . . Boston—Bernard P. Goldsmith was appointed quality control manager for the receiving tube division of Raytheon Manufacturing Company sometime last fall. Congratulations are better late than never.

. . . Cincinnati—The officers elected for the coming year are—Don Brandt, president; Ray Hauck, vice president; Bill Eilrich, secretary and Mrs. Ada Diehl, treasurer.

. . . Corning-Elmira—Thomas J. Hohn has been named quality control supervisor of the Muskogee Plant, Corning Glass Works.

. . . Los Angeles—Frank Vlasak has been promoted to quality control engineer for inertial navigation products of the Autonetics Division of North American Aviation, Inc.

. . . Mid-Hudson—Nicholas H. Hemmer, Jr., has been promoted to project manager of the plant and field suggestion departments at IBM, Poughkeepsie.

. . . Milwaukee—Commander Robert Mallek, U. S. N., has recently been transferred from the San Bernardino area to the Milwaukee area as Inspector of Naval Material.

. . . Minnesota—Merm Olson of Telex has been promoted from staff quality control engineer to director of quality control.

. . . New Haven—George S. Georgia, past secretary of the section and formerly of the Revere Corporation of America, has recently accepted the position of quality control engineer with American Machine and Foundry at Raleigh, N. C.

. . . Northeastern Indiana—Newly elected officers are: Ellis B. Cash, Inspector of Naval Material, secretary; Ardith Carter, Dana Corp., vice president; Joseph H. Cline, General Electric Co., president; and Harry B. Richardson, General Electric Co. treasurer.

. . . Pittsburgh—C. R. Stadterman has left the area and taken a new position with Allegheny Ludlum Corp. in Dunkirk, N. Y.

L. F. Jones has been promoted to superintendent of quality control at the Youngwood plant of Westinghouse Corp.

John De Canio, until recently QC supervisor of the Homestead plant of Continental Can Co., has been promoted to division resident inspector.

A. I. Kaufmann has taken a position with Bell Telephone Laboratories and is no longer in the Pittsburgh area.

. . . San Antonio—Section vice chairman Emzy S. Garrett has been promoted to the office of assistant personnel manager of Friedrich Air Conditioning, Inc.

. . . San Bernardino—Congratulations to section chairman E. G. Gustely on his recent promotion to quality control manager of Aerojet General Corp., Azuza.

. . . San Francisco Bay Area—Robert L. Pappas, manager of quality control for Ampex Corp., has been elected an officer of Ampex Corp. by the board of directors.

. . . Toledo—Congratulations to Ray E. Crouse on his appointment as a director of the Engineering Society of Toledo. Ray, employed as process engineer at the Dura Division of Detroit Harvester Company, is immediate past president of the Toledo Technical Council.

. . . Toronto—The entire section extends its congratulations to R. A. Lucas, project manager of quality control for IBM, upon his election as a Fellow of the Society.

The popular chairman of the Toronto all-day forum, Wm. (Bill) Foskett, has accepted a position as chief inspector and quality control manager with Flight Refuelling Canada, Ltd., Rexdale, Ont.

H. C. (Cliff) Hilditch has joined Canada General Electric Co., Ltd., Toronto, Lamp Division, in the function of specialist statistical methods.

clinics, conferences, and courses

JUNE

. . . ***23-July 2***—15th Annual Rochester Institute of Technology "Quality Control for the Chemical Industries" Course, contact Robert D. Pease, Associate Director, Rochester Institute of Technology, 65 Plymouth Avenue South, Rochester 8, N. Y.

. . . ***30-July 11***—Short Course in Statistical Quality Control, The University of Mississippi, University, Miss., contact Department of Conferences and Institutes, University Extension, University, Miss.

JULY

. . . ***21-Aug. 1***—"Mathematical Analysis and Simulation in Industrial Operations" course, Massachusetts Institute of Technology, Cambridge, Mass., tuition $300, contact Herbert P. Galliher, program director, Operations Research Project, Massachusetts Institute of Technology, Cambridge 39, Mass.

. . . ***28-Aug. 1***—"Tolerance Management," Statistical Summer Seminar, MIT Endicott House, Dedham, Mass., contact Irving Weiss, Bell Telephone Laboratories, North Andover, Mass.

. . . ***28-Sept. 6***—Undergraduate and Research Seminars in Statistics, University of California, Berkeley, Calif., contact David Blackwell, Chairman of the Department of Statistics, University of California, Berkeley 4, Calif.

AUGUST

. . . ***4-8***—"Design of Industrial Experiments," Statistical Summer Seminar, MIT Endicott House, Dedham, Mass., contact Irving Weiss, Bell Telephone Laboratories, North Andover, Mass.

. . . ***4-22***—Industrial Reliability Course, University of California at Los Angeles, contact Prof. Edward P. Coleman, Coordinator, Industrial Reliability Course, Department of Engineering, University of California, Los Angeles 24, Calif.

. . . ***11-22—Statistical Methods in Industry Course, sponsored by the Department of Engineering of the University of California at Los Angeles and the Los Angeles section of ASQC, contact Prof. Edward P. Coleman, Coordinator, Statistical Methods in Industry Course, Department of Engineering, University of California, Los Angeles 24, Calif.***

. . . ***18-28***—11th Annual Ten-Day Quality Control by Statistical Methods Course, University of Michigan, Ann Arbor, Mich., contact Prof. C. C. Craig, 106 Rackham Bldg., Ann Arbor, Mich.

. . . ***29-Sept. 1***—Statistical Conference, University of St. Andrews, Edinburgh, Scotland, sponsored by Royal Statistical Society, contact St. Andrews Conference, Attn: Miss U. Croker, Royal Statistical Society, 21 Bentinck Street, London, W.1, England.

SEPTEMBER

. . . ***8-19—Eight Basic Industrial Engineering Courses (Quality Control, Psychological Engineering, Motion and Time Study, Collective Bargaining for Engineers and Materials and Process of Manufacturing, Elements of Integrated Data Processing, Engineering Economy, Tool Engineering, Plant Layout and Materials Handling, and Production Control), University College, Washington University, St. Louis, Mo., sponsored by the Department of Industrial Engineering and the University College at Washington University and the St. Louis sections of ASQC, AIIE, ASME, ASTE, AMHS, ACM, and SAM. Contact University College, Washington University, St. Louis 5, Mo.***

. . . ***15-19***—13th Annual Instrument-Automation Conference and Exhibit, Philadelphia Convention Hall, Philadelphia, Pa., sponsored by ISA, contact Fred J. Tavery, Exhibit Manager, Instrument-Automation Conference and Exhibit, 3443 So. Hill St., Los Angeles, Calif.

. . . ***22-24***—7th Annual Meeting of the Standards Engineers Society, "Standardization — A

(September, continued)

Must for the Space Age," Benjamin Franklin Hotel, Philadelphia, Pa., sponsored by SES, contact F. F. Van Atta, 1916 Race St., Philadelphia 3, Pa.

. . . 23-26—Iron and Steel Exposition and Convention, Cleveland Auditorium, Cleveland, Ohio, sponsored by Association of Iron and Steel Engineers, contact Association of Iron and Steel Engineers, 1010 Empire Bldg., Pittsburgh 22, Pa.

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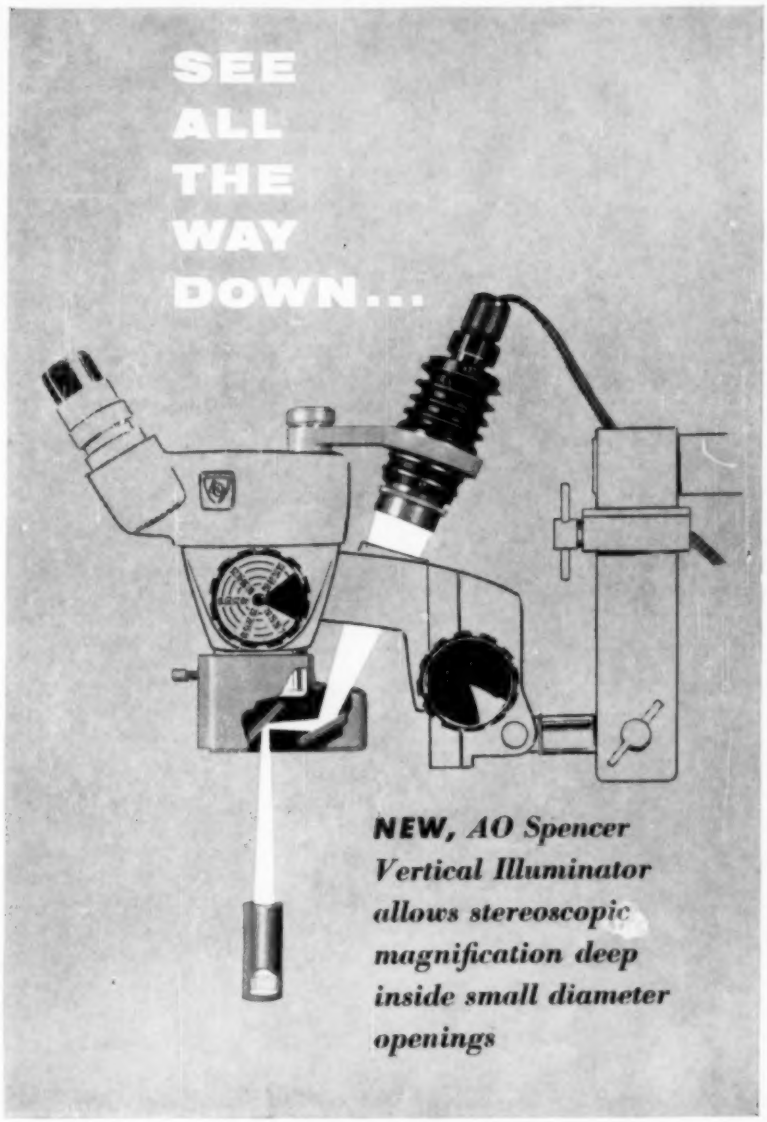
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